PLANT ECOLOGY

THE DISTRIBUTION OF VEGETATION IN THE BRITISH ISLES, ARRANGED ON A GEOLOGICAL BASIS

BY

MARY A. JOHNSTONE

B.Sc., F.L.S.

Author of "Matriculation Botany," &c.

WITH 18 HALF-TONE ILLUSTRATIONS

1928

LONDON & TORONTO

J. M. DENT & SONS LTD.

NEW YORK: E. P. DUTTON & CO.

PRINTED IN GREAT BRITAIN

PREFACE

THE importance of Ecology as a branch of botanical, agricultural and geographical studies is beyond dispute. Since the beginning of this century, when the investigation of British vegetation was in its infant stage, the number of workers attracted to it has steadily increased. Much very arduous and distinguished work has been accomplished, the results of which have been presented in various publications. Scattered as the accumulated knowledge is throughout so many periodicals and pamphlets, it is not readily available to the younger botanical student, to the teacher of geography, or to the general reader. It is hoped, therefore, that this unpretentious attempt to bring together in simple form some of the records made on British vegetation may be helpful; it may encourage some readers to study original monographs bearing on the subject, and perhaps may even incite a few to enlist under the banner of the field ecologist. Some personal observations are incorporated in the book, but I acknowledge very sincerely my indebtedness to the far more important work of others.

I am under very peculiar obligation to Dr. W. G. Smith, who took the trouble to read and criticise my manuscript, and whose expression of opinion gave me sufficient confidence to make my venture. I regard it as an honour to have received such help from one of

those two brothers who were the pioneers of British ecology.

My difficulties relating to illustrations have been overcome for me by the generosity of various distinguished ecologists. I wish to express my gratitude to Mr. Frank Elgee, Dr. E. Pickworth Farrow, the Rev. T. A. Jefferies, Professor Oliver, Dr. Munn Rankin, Dr. W. G. Smith and Mr. Albert Wilson. Manchester Municipal Waterworks Department has kindly lent me the photograph of their afforestation area by Mr. G. P. Abrahams. To Mr. W. B. Crump and Mr. R. M. Adams I owe illustrations of Pennine and Highland scenery.

To my publishers I owe many thanks for courteous guidance and extreme care.

M. A. J.

CONTENTS

LIST OF ILLUSTRATIONS

Descriptions of detail and acknowledgments are printed underneath the illustrations.

PLANT ECOLOGY

CHAPTER I

PLANT ECOLOGY

PLANT ecology (Gr. *oikos*, a home) is a branch of botanical study which concerns itself with plants as they grow in their natural habitats or dwelling-places. It must be based, in the first instance, on the individual plant and its requirements. It goes on, however, to consider plants as communities—just as one may link together the study of individual human beings with the study of their social systems.

The plant, in its relationship to its surroundings, brings in two sets of problems. Firstly, there is a very complicated set of conditions to which it re-acts—climate, soil, topography, etc. Secondly, there is keen competition between possibly scores of species of plants to get and maintain a footing in the same spot; this implies evolutionary questions about plant characters and the principles governing changes in them.

Increasing attention has been paid in recent years to ecology, and there is increasing need that it should be so. The population of the world is growing, therefore the world's food supply must grow greater. A large proportion of the world's most productive and most accessible land is already under cultivation. It is becoming a more pressing necessity to make use of the poorer land,

and to exact the maximum yield from the best. The study of natural vegetations is the broadly fundamental basis on which schemes of cultivated vegetation are founded; experimental botany is a close ally working with the same aim.

Many systems of classification and nomenclature have been advanced since first ecology became a popular branch of botanical study. There is not even yet general agreement as to definitions and terms. Only the most important and most generally accepted can be mentioned here.

The term of widest generalisation is that of *community*. This can be used in speaking of any assemblage of plants which shows a distinct individuality; the assemblage may belong to any one of the grades referred to below. *Vegetation unit* is also a general term used in speaking of any plant-covered area which has boundaries which mark it off from other unit-areas of vegetation. Such an area may be large or small, but it always possesses peculiar characters which give it an individuality. Vegetation units are not theoretical; they actually exist in nature and their definition is framed directly from nature. The "personality" of the "unit" is the expression of the interaction of a large number of factors which act upon the plants which comprise the unit. The sum total of these factors represents the plant's *habitat*; this term is also used in the narrower sense of the actual place in which the plants grow. The character of a community may be due in the main to the dominance of one species of plant, which, therefore, is called the *dominant*; e.g. the ash-tree in an ashwood. There may be two species of about equal rank—*co-dominants*; or the second species may be rather less important—a *sub-dominant*. Other

members of the community are *subordinates*. A *closed* community is one in which the vegetation is stabilised, into which new members are scarcely likely to find entrance. An *open* community is one in which the ground is not fully occupied by plants, one which is changing. A community which has not been disturbed, materially, by man is a *natural* unit of vegetation; one which he has altered (e.g. grassland which is grazed by his flocks and herds) is *semi-natural*; one which he creates and controls (e.g. a wheat-field) is a *cultivated* or *artificial* community. All of them lie within the province of the plant ecologist.

It is a difficult piece of work to settle the limits of plant communities, and to choose the best names for them. It will only be by studying the history of the development of this branch of botany, and by comparing the various systems of nomenclature, that the student will be able to reconcile the frequently contradictory uses of terms. Some of the publications in the list at the end of this book will assist him.

One of the pioneers in ecology was A. F. W. Schimper, who did great work in direct investigation, and also in bringing together in a fine book the work of others. He undertook in it the mapping out, on broad lines, of the vegetation of the world. He chose a standard vegetation unit which suited the magnitude of his subject, namely, the *Plant Formation*. His three great vegetative regions are *woodland*, *grassland*, and *desert*.

He discusses the factors of environment which may be responsible for the prevalence of any one of these, and concludes that over great world areas the *determining* set of factors is climatic. He works from zone to zone of latitude, and within each correlates the vegetation,

in the main, with the *water-supply available for plants*. Within his extensive climatic formations he recognises more limited sub-divisions which are determined by *edaphic* or soil factors. Instead of adopting an entirely new unit term for these, he refers to them as *Edaphic Formations* (e.g. mangrove, within the *Climatic Formation* of Tropical Forests).

It is not, however, with areas such as Schimper's that we are dealing in the British Isles, and it is found here that the relative weight given to climatic and edaphic factors must, as a rule, be the reverse of Schimper's.

The systematic survey of vegetation and the mapping of results was begun in this country by Robert Smith, who had studied the system in Switzerland. His investigations were carried on chiefly in the Lothians of Scotland and in Perthshire. His brother—Dr. W. G. Smith—has been one of the most distinguished of the investigators who have followed him. He was one of the most prominent members of a committee which was formed in 1904 to study British vegetation. In 1913 the committee expanded into the British Ecological Society, whose official publication is the *Journal of Ecology*. In 1911 the results of the individual and combined efforts of the committee were published in book form as the *Types of Vegetation*, edited and to a large extent written by Professor A. G. Tansley. Many references to this book will be found in the following pages; any treatment of the subject in a class-book of this type must necessarily be based on this and other publications of British ecologists. As many as possible of those listed in the appendix should be read. The classification of plant communities which is adopted in the *Types of Vegetation* and the terms used there have

been so generally accepted and so long used by British botanists that they will be retained throughout this book.

The definition, or rather description, of a *Plant Formation* which is given there (page 4) is as follows: "A plant-formation is the natural vegetation occupying a habitat with constant general characters, which determine the communities of plants occurring in that habitat." Whilst to climate is allotted some influence on habitat, edaphic characters are regarded as having a more direct effect, so that "on the whole the plant-formations of the British Isles are *mainly* determined by edaphic factors, i.e. by soil" (page 6). Some modifications of the views expressed in the *Types of Vegetation* are embodied in an article in the *Journal of Ecology*, June 1921, by Professor Tansley.

Within the formation there can generally be recognised sub-communities; for instance, on the chalk or other calcareous soil there might be woodland, scrub and grassland. To these is assigned the name *Association*. They, too, would often be edaphic in origin. Further, within the woodland there might be well-defined sections dominated by one or two species, e.g. bracken; these constitute *Societies*.

The chief plant formations originally identified in the British Isles are:

(1) Formation of clays and loams.
(2) Formation of the coarser sands.
(3) Formation of the older siliceous soils.
(4) Formation of calcareous soils.
(5) Heath.
(6) Moorland.
(7) Fen.
(8) Freshwater, marsh.

(9) Freshwater, aquatic.
(10) Salt-marsh.
(11) Sand-dune.
(12) Shingle-beach.
(13) Several arctic-alpine formations.

The first three of the formations are determined by the physical characters of the soil in each case. The fourth, directly or indirectly, depends on the presence of calcium carbonate. Heath and moorland bring in questions of acidity in varying degree. The next three formations are dominated by an excessive water-supply which is alkaline. Salt-marsh, sand-dune and shingle-beach are xerophytic (p. 16), and often halophytic (p. 20) habitats. The last formations belong to the high mountains.

The classification of British vegetation quoted above expresses the opinions of the ecological workers concerned, at the time the *Types of Vegetation* was published. It was, naturally, regarded as provisional and quite likely to undergo modification as investigation proceeded. Already other classifications have been adopted by some workers. According to one scheme the working standard unit is the *Plant Association*; sub-divisions of this are known as *Consociations*; and further divisions as *Societies*. Examples of the first would be the ashwood and the fen; of the second, the ling community within a heath association; of the third, a bilberry patch amongst the ling.

CHAPTER II

CHAPTER II

MODIFICATIONS OF PLANT FORM, CORRELATED WITH ENVIRONMENT

THIS chapter ought to be a very long and very full one, in order to render the subject quite intelligible and as interesting as it really is; it will, on the contrary, as being subordinate and preliminary to the main subject of this book, have to be very short.

The whole complex of problems which is involved in the correlation between the plant and the conditions in which it exists is one which grows more involved and more perplexing, the deeper the investigation into its secrets is carried. Early theories were eminently simple and widely accepted. As an example of one of them, reference may be made to that which saw in every divergence from normal plant-form a definite and purposive adaptation designed to secure some advantage for the plant, e.g. the bright colour of hedge fruits was a device to attract birds and provide adequate dispersal of seeds, whilst the spines on gorse were quite manifestly called into being to protect the plant from grazing animals—and so on. It is well known now that these assertions do not meet the case. To formulate theories, to find them inadequate or misleading or totally wrong, to modify them or discard them, to seek for other explanations—has been a sequence which has run its course over and over again in the history of this branch of botany. The scientific

investigator must be scrupulously honest with his fellow workers and with himself; he must never hesitate to follow up evidence which promises to be hostile to his own theories, nor to throw his theories overboard, publicly, as soon as he is convinced that they are unsound.

It is clear that all relations which hold as between a plant and the factors which operate in its surroundings of air and earth and water must be scrutinised with very watchful regard as to which are causes and which are effects. It must be kept as an open possibility that what appears as a relationship of cause and effect between two phenomena may have to be interpreted through the introduction of a third factor, at first unsuspected. These questions are discussed fully in special textbooks, which may be consulted; more and more, however, is it becoming necessary to refer to the monographs of those workers who are devoting themselves to special branches of the subject, much more limited in range than in the early days of research. Some of these authorities are cited at the end of this book.

The knowledge of a plant's physiological system, of the essentials upon which its life depends, is gained by experimental and observational research. Such research demonstrates the normal plant's requirements in respect of water, of food other than water, of air, of light, etc.; it deals with the effects of temperatures and of wind action; it takes note of the mutual relations of plant and animal.

What may be regarded as a normal plant will have its needs met in an environment of moderate conditions. Where conditions are extreme, e.g. excessively dry, or very badly illuminated, the plant-form may be found

Photo, R. M. Adam

FIG. 1. ROTHIEMURCHUS FOREST, STRATHSPEY

Pine-trees at all stages arise from a moor densely covered with ling (*Calluna vulgaris*) and bilberry (*Vaccinium Myrtillus*).

to be abnormal; this is where the reader must steer his course very carefully amongst the accumulated facts, and be wary of adopting conclusions about them. The matter of the plant in its relationship to soil will be entered upon in Chapter III.; some of the other points we will refer to, very briefly, in this.

A. **The plant's water-supply** is of such supreme moment to it that the variations in form which are related to it in some manner or other are very striking. In the main, there are involved two aspects of the problem—the degree of ease with which the plant can obtain what it requires, and the degree of surety with which it can retain it.

The following are conditions in which supply may be defective.

(i.) There may not be a sufficiency of water in the soil; or the supply may be liable to fail at certain seasons. A desert area which is practically without rainfall supports no vegetation at all. Some deserts have a very short rainy season yearly; during the long dry season the plant's life-current is slowed down almost to stagnation; when the gracious rains reach its roots it suddenly opens forth into vigorous beauty. Parts of other deserts bear wonderfully free and fresh growth; the hidden source of strength is in the gentle steady stream which is soaking its way underground down the rock-gradients—the rain which has watered the earth perhaps many miles away.

(ii.) Even where water is quite plentiful, it may, for various reasons, be of no service to the plant. It has to make an entry into the plant tissues, and this is a process which depends upon the functioning of living tissues. In very close touch indeed with the soil particles and

the soil-water lie the finest of the hairlike rootlets; close to their tips the rootlets bear a delicate silky growth of what are known as root-hairs. They are not hairs, but very long soft-walled cells, belonging to the epidermis; they are peculiarly intimate with the soil-grains. These root-hairs are the points of entry for water, and from the living character of these absorbing organs it will be seen how likely it is that there will be very fine adjustment of conditions of action.

It is well known that for every function which is vital to a plant there is a particular temperature at which that function may be carried out to perfection. For every function also, varying from plant to plant, there are two other important temperatures—a maximum, above which the process breaks down, and a minimum, below which it stops. Thus, below a certain temperature, the function of absorption of water by root-hairs cannot go on. In a cold soil, water may be plentiful but quite valueless to the plant.

(iii.) There is another state of the soil in which plants may suffer water-starvation, although water is far from being lacking. This is the result of the high percentage of salts of various kinds which are dissolved in the water.

The soil-water is the channel by which soluble food in the form of salts is taken into the plant's tissues. Within the individual cells of these tissues is another fluid, in which salts are dissolved. There is, then, a salt solution within the cell and one outside the cell; the former must be maintained at a certain strength; the latter must be perpetually replenishing the internal stores. There must be an unceasing and intricate series of adjustments, the factors contributing to which are very many. It is a

general law that the ordinary plant thrives only when the soil-water is a very weak solution of soil-salts. If the soil-solution is highly concentrated, the plants fail to make use of it, and again there is starvation in the midst of plenty. In this case again, however, there are plants which, differing in certain particulars of structure from the normal plants, can exist in these highly impregnated soils. Such are the plants of the salt-marshes.

The divergencies of form associated with water-supply are so great that plants have been classified on this basis. The chief groups are:

(*a*) **Hydrophytes** (Gr. *hydor*, water). This is a group which flourishes in situations where water is superabundant; they are the plants of the fresh-water marshes and the aquatics of the ponds and lakes.

(*b*) **Hygrophytes** (Gr. *hygros*, moist), inhabit such places as deep, shady, tropical ravines, in which the air is rarely far from saturation point. The structure of the epidermis of a plant which belongs to the average habitat is so designed that the rate at which the plant parts with the water in its leaf-cells is efficiently regulated—the need being, on the whole, to prevent the plant from losing water too rapidly. In the hygrophyte, however, this transpiration, or loss of water, must be encouraged, and the peculiarities of structure which have enabled the hygrophytic group to survive, have this effect. The leaves are thin and often large, their stomata are numerous and well-exposed, their epidermis is thin.

Hygrophytes[1] are of rare occurrence in the British Isles; probably we can include among them only the

[1] The term "hygrophyte" is by some applied to a plant rooted in water-logged soil but not immersed in water.

filmy ferns found in the warm, moist, still situations which occur in south-west Ireland and the Isle of Skye.

(*c*) **Xerophytes** (Gr. *xeros*, dry), are plants which are so constituted that they are able to live in habitats where there is danger of desiccation. This danger may arise from either a low rate of intake of water or a high rate of loss. The case of deficency of supply is outlined on page 13. The other case—transpiration in excess of absorption—may be seen illustrated in the garden plants wilting in the heat of a summer's afternoon, reviving when night-time brings a fall in transpiration and a recovery of internal water-balance.

A dry wind, even when cold, may rob the leaves in spring-time and leave them shrivelled; the dry, cold winds of the Arctic lands kill off every bud or twig which tries to rise above certain levels, and this not by the direct action of temperature, but by abstracting moisture. The plants of the moorland have to endure both untempered sunshine and sweeping wind.

The causes mentioned above are very diverse, and with more space at disposal one might pursue them into many variations; correspondingly there is extreme diversity in the habitats in which xerophytic forms prevail. Such are:

(i.) Hot rainless deserts.

(ii.) Thin soils overlying rock, e.g. on mountains.

(iii.) Screes of loose material on mountains.

(iv.) Sand-dunes.

(v.) The trunks, branches and leaves of trees which support epiphytic growth in the tropical forests.

(vi.) Very cold soils, as in Polar regions.

(vii.) Soils in which large quantities of salts have lodged, e.g. those of salt deserts, shingle-beaches, etc.

(viii.) Peaty soils.

(ix.) Mountains and high moors exposed to intense insolation and strong winds.

In (i.) to (v.) there is actual dearth of water.

In (vi.) absorption is checked by the low temperature of the soil-water.

In (vii.) and (viii.) soil solutions are too strong; peat is also harmful in other ways.

In (ix.) sun and wind carry off those supplies which otherwise might have been sufficient.

It may now be clear how difficult it often is for a plant to get and keep what water it needs. When it succeeds, what is the specialised equipment which has given it the victory? And here it must be clearly understood that no suggestion is being made as to how that equipment came into existence. That is a very difficult problem to solve, and we do not need to tackle it here.

Peculiarities of structure which are linked with water difficulties may be arranged in three groups:

First, the plant's power of absorption may be increased. Roots may lengthen to a tremendous extent. The collector of plants from the screes of the high mountains may get hot and weary before he unearths the seemingly endless root of a plant whose shoot measures an inch or two. We are told that the roots of some of the desert inhabitants run downwards for dozens of feet in pursuit of moisture. In other individuals, when the moisture lies in the upper layers of the soil, the root-system is many-branched and widespread laterally.

Second, the plant may be furnished with reservoirs. When supplies are good, these are filled; during drought they can be drawn upon. The reservoirs, or water-tanks,

are the soft-walled tissues. They may enlarge to huge proportions. On a small scale they are illustrated by a leaf which loses its flat, thin outline, and becomes rounded and succulent; the leaves of the many stone-crops and house-leeks which flourish on exposed rocks at high altitudes are of this type. In a South American desert-plant of tree dimensions, the trunk is swollen into a gigantic water-cask. The massive stems of cacti are sodden with water; their leaves are hard spines. In other desert-plants, it is the roots which have become enlarged and watery. We see the same modification acting in plants growing in salt soils, like the salt-wort of the saline marshes.

Third, the transpiration rate may be checked. Knowing that it is chiefly through the leaves that the water is lost, we turn naturally to see what may happen to them. The most drastic happening, of course, would be the complete disappearance of the leaf. This does actually take place. When winter cold reduces the absorptive root-hairs to inactivity, the deciduous tree of the temperate regions parts with its leaves; it becomes a xerophyte for the winter. Again, there are individuals in the deserts which, for all practical purposes, have got rid of their leaves for all seasons. As a plant must possess the green assimilating tissue which is characteristic of leaves, a substitute for the leaf must be found. The difficulty is overcome by the development of green tissue on small branches (as in broom) or on thick stems (as in cacti). Bulk for bulk, the twig has less surface exposed than the leaf and that surface lies less directly in the line of the sun's rays.

Pines and heaths are examples in which the leaf area is much smaller than usual.

Associated with the lessening in the amount of soft green tissue is the preponderance of hard woody tissue; hence thorns and spines; hence the spiky gorse of our exposed wastes, and the dagger-like thorns of the acacias of the desert. The non-development of the soft tissue is consequent upon the scarcity of water, and in some plants its re-appearance can be induced by furnishing them with much water.

When leaves retain their full size, the under-surface, on which most of the stomatal openings are generally situated, as well as the upper surface, may have the exit of water impeded by screens of hairs, or coatings of wax or scales. There are to be found all degrees of hairiness up to the fluffy, all-over garment assumed by the alpine edelweiss. The cudweed of the English hills follows suit.

In such leaves as those of holly, the epidermis is thick and waterproofed.

The stomata are the danger-spots in the leaf, the openings into the tissue-systems, through which gases pass in and out in regulated measure. Fierce heat or thirsty wind may overcome the beautiful mechanism controlling the opening of the doorways. Safety for it is found in many ways which look, almost, like skilfully planned devices. For example, many of the grasses and heaths of the moorlands and sand-dunes possess leaves which, either permanently or at need, are rolled into a loose cylindrical form. The stomata open into the spaces so enclosed and enjoy their moist shelter; hairs may help to shut off the enclosures from the dry air outside. In broom, the stomata line the longitudinal furrows on the green stems. These are far from exhausting the list of alterations, but they suffice as illustrations.

Most plants inhabiting high altitudes and latitudes are characterised by a very low habit of growth. Trees disappear, and shrubs grow more and more stunted. The tall herbaceous stem with lengthy internodes is replaced, in the extreme, by a "rosette" form, in which nodes approximate and successive leaves lie nearly in contact. Some such can survive months of drought, resting on a hot rock slab, rooted in a narrow rock crevice. The "cushions" and "mats" of the alpine saxifrages, etc., are close-packed masses of short branches. The principal, direct causes of this stunting are the defective state of nourishment following upon the poor water-supply, and the retarding influence of strong light on the lengthening of shoots. The short stature serves the plant in many ways of which it concerns us to note these—that the searching winds of the hill-face are a little less cruel near the ground, that what moisture there is in the soil will have a chance of salvation through the close-fitting plant covering, that leaf overlapping leaf will form the walls of shady chambers, into which stomata can open their doors with reasonable safety.

(*d*) **Halophyte** (Gr. *hals*, salt) is a special name given to the plant of the xerophytic habitat which is rendered so by salts in the soil. Often, the halophyte has succulent leaves or stems, or both.

(*e*) **Mesophytes** (Gr. *mesos*, middle) occupy a middle place in the scale between hydrophytes and xerophytes. They stand for the plant which finds itself in an environment which ministers to its requirements in such a way that there are no curious departures from the type of plant-form which is accepted as normal. Root and shoot attain fair proportions according to species and neither

become bloated with moisture nor pinched and distorted for want of it. Leaves are green and spreading, moderate in size, transpiring with regularity and in safety.

Mesophytic trees are never leafless. That implies their absence from Britain, for our cold winters mean leaf-fall to all but the pine or the holly type, with their leaves xerophytically modified. The deciduous tree can only be classed with the mesophyte if we restrict the use of the term to the leaf-bearing period of its existence.

(*f*) **Tropophyte** (Gr. *tropos*, change) is a term applied to those plants which are like hydrophytes or mesophytes during the period of the year when they can get all the water they need, but like xerophytes during the period of drought. The drought may be due to the low temperature of the soil in winter, or to rainlessness as in the dry season of the monsoon regions. Thus our deciduous trees are tropophytes. So also are corms and bulbs, and all the herbaceous plants in which aerial parts die down in winter.

B. **The plant,** no less than the animal, **requires air,** and it must also free itself of the gases which arise in its tissues. The stomata are the doorways in which we may imagine these incomers and outgoers to be jostling one another. Upon their free entry and egress depend the processes of assimilation. The doorways must not have obstacles placed in front of them. Of what nature might such obstacles be? Look at a leaf drenched with fine rain, with mountain mist, and you will find one answer. If the surface texture of that leaf is such that thin water films fit closely to it—both sides, for the water slips round underneath—the pores may be closed. The hill-tops are homes of mist, and, therefore, homes of danger

for their plants. Up there, the season of growth and flowering and seeding may be very short, and no day of it can be spared. And misty days come in that short summer. So wherein lies a remedy? A peculiarity which serves other purposes comes in useful on these occasions, namely, the hairiness of leaves and stems. It is evident that the hairs will prevent close application of water drops to the epidermis, and passage of gases will continue into the spaces amongst the hairs, whilst drops will shake off more readily.

Another situation suggests itself—the low-lying meadows and the dank stream-margins; there we find coltsfoot with its web of hairs, and pale willows with their soft underfelts.

Steamy ravines in the tropics drip perpetually with moisture; there grow plants with "velvety" leaves, on which fine projections of the surface—the velvet pile—act precisely as do the hairs in keeping the stomata clear.

C. **The plant must have light:** it must have enough of light: it must not have too much light. If set in dim light, it develops certain marked characters; if it has to face the glare of the sun the fact is equally recognisable in its appearance; the "shade" plant and the "sun" plant present strong contrasts.

The effort, *speaking figuratively,* to reach up to the light is responsible for the whole race of climbing plants, in which we see exaggerated growth of axis—culminating in the hundreds of feet of the lianes which triumphantly flaunt their flowers above the trees of the tropical forests. The reverse habit strikes even the unscientific climber on an alpine pass—the more and more lowly forms assumed by the plants seen as he mounts the higher.

Towards the growth of the plant-shoot, light is not favourable. Our own bluebell can show us another effect of light. Fine and free and upright its leaves spring in the woodland, its shady home. Let the wood be cleared away and the sunshine in its strength fall on the bluebell: its leaves cower close to the ground like so many flat rosettes.

Absolutely essential as is (with a few exceptions) a moderate degree of illumination for the formation of the green colouring matter of leaves, the chlorophyll, just as surely will excess of sunlight destroy that chlorophyll. The plant will be faced with this danger in the desert glare, in the strong rays reflected from the mountain rocks, in the radiance of the sun-lit moors. What are the safeguards? Many and varied; effectual, however they may have come into being. Those same grey, hairy coats, which turned aside the droplets of mist and which saved for the leaf the water in its cells, can act again as protecting screens for the little green bodies in the leaf cells.

It seems to have been proved, too, that one colouring matter which exists in some plants can save another from destruction without itself being destroyed; that the purplish-red *anthocyanin* can shield the chlorophyll. Many mountain plants are deeply tinged with red in their aerial parts, and it beautifies young spring growth at all levels. A long series of experiments carried on between lowland and alpine stations has furnished proof that some lowland plants can adapt themselves to life at high elevations, and that their success depends, most often, on their being able to produce the red colouring matter.

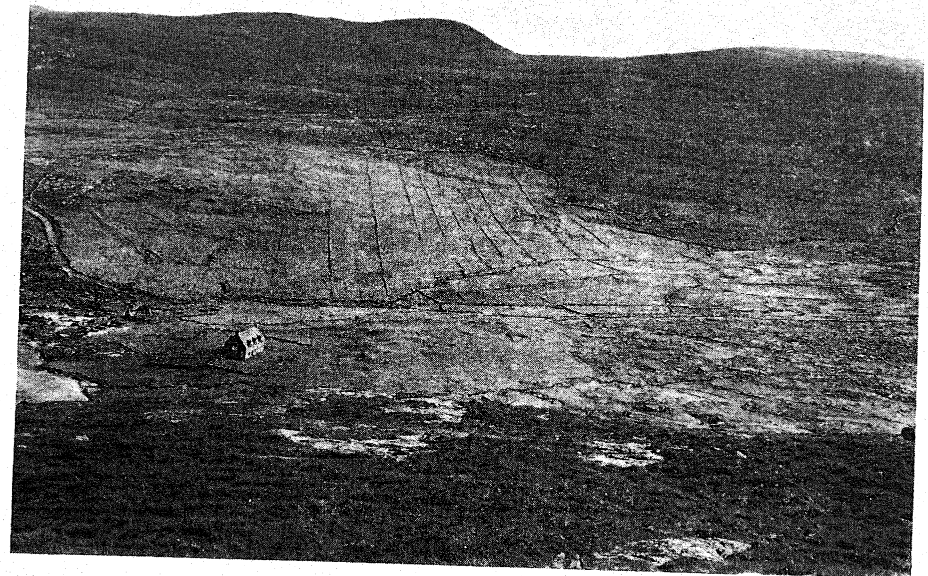
Coverings of waxy or "mealy" character also serve as protectives in some alpine plants.

D. **The protection of seemingly delicate plant-tissues from cold**—that is, from suffering *directly* from a low temperature—at first strikes one as certainly requisite. However, the evidence now accumulated seems to teach us that the protoplasm, the vital substance of the plant, can resist very low temperatures. For example, the minute pink algæ, "the red snow" of the high Alps, though mere specks of naked protoplasm live their lives on the snowfields. The delicate flowers of the mountains may be stiff with the night frost, yet fresh and fair next day. Travellers describe flowers of Arctic lands which may survive the freezing of a whole winter and resume progress in the following spring.

Many of the effects which used to be attributed to low temperatures are now known to be due to the drying up of tissues. For instance, cold winds kill tender plants by extracting the moisture from the buds and young leaves; again, cold soil may kill by stopping for too long the flow of water into the roots.

E. **The strength of the winds** prevailing in a district, their temperature, moisture and frequency, form a factor which materially affects the character of the vegetation.

Very particularly does the wind enter into the question of forest-growth. Strong persistent winds, especially cold winds, are very unfavourable to trees. The strata of air in which the buds and young twigs of the tree are spread abroad are the run of more violent gusts of air than the strata nearer the ground. The buds are dried up, and young leaves shrivel and drop. The woody plant



Photo, R. M. Adam

FIG. 2. LEWISIAN GNEISS OF BARRA ISLES

The dark-coloured area of natural vegetation has as dominants sheep's fescue grass (*Festuca ovina*) and deerhair sedge (*Scirpus caespitosus*). The cultivated part—"intake" from the moor—formerly bore crops, but is now grassland.

may never get beyond shrub stature; the squat crouching tangle of branches has the best chance of survival, so a wood may never get a footing or may be killed off. This may be one of the reasons for the treeless condition of the western and northern islands of Scotland, where the few trees are tucked away in the little sheltered valleys; the isles are in the track of the wild north-west and northern winds.

From height to height in the mountains, the climber passes from tree form to shrub form, and from shrub to "mat" form. The destruction of buds is not the only or even the main cause of this dwarfing, as has been seen, but the diminution of stature as the situation becomes more exposed to gales does bring a measure of safety from them.

CHAPTER III

CHAPTER III

CLIMATE AND SOIL OF THE BRITISH ISLES

I. *Climate*

WITHIN the comparatively small area of the British Isles, the edaphic group of factors has the more direct and pronounced influence on the character of the vegetation. Nevertheless, climate cannot be disregarded—neither its direct effects due to variation in temperature and rainfall, nor its operation on soils and on topography. Hence we must know something of the local climate, even when we are chiefly concerned with vegetation in its relationship to rock structure.

The term climate, taken in its widest sense, covers all the weather phenomena of a place, including temperature, light, winds, ocean currents, rainfall, snowfall, and humidity of the atmosphere. Our task now is to ascertain what climatic facts are true for the British Isles; explanations of these facts we do not undertake. It will be necessary also to lay stress on those facts which more particularly have a clear bearing on questions of vegetation.

A. **Moisture Conditions.** Under this head fall the average yearly rainfall in different localities, its seasonal distribution, the rain-determining winds, the character of the rainfall, snowfall, and the rainfall-evaporation ratio.

Our islands have a rainfall of moderate quantity. The

western side has decidedly more rain than the east. Winds from the west and south-west blow about twice as frequently as those from any other direction, and without prolonged breaks. They are warm winds and they have travelled over the surface of an ocean, therefore they are likely to be moisture-laden. Part of their journey has been over the warm current of the Gulf Stream. As they are travelling towards the cooler north their water-containing capacity will diminish. The configuration of the west coasts will increase the likelihood of rainfall. From Cape Wrath to Land's End, with some breaks, there runs high hill-land. Approaching this, the air-currents are forced upwards; they cool in doing so, and part with their moisture in heavy rains on the western side of the mountains. The air-currents descend on the eastern side, and, rising in temperature, are less likely to give up what is left of the water-vapour. Where there are gaps in the hill line, as in the Scottish central plain, there is less marked difference between the two sides of the island. The southerly element in the wind is much less strong in summer, and west and even north-west winds are then stronger; hence slightly cooler and drier effects than with the southern element present.

The eastern counties have the altered west and south-west winds, and also winds from the east and north-east, which are at their strongest at the close of winter and in spring. These winds originate on the Continent, and are markedly cold in spring and lacking in moisture. They are harmful to vegetation, killing the opening buds and the tender leaves by depriving them of moisture. Only late spring growth can survive in the places where they prevail. The following are particular instances of the

By courtesy of Albert Wilson

FIG. 3. LIMESTONE PAVEMENT WITH JUNIPER THICKETS: WARTON CRAG, NEAR CARNFORTH

above generalisations. In Ireland the extremes of east and west are not as great as in Britain; the wettest parts are western Kerry and west Connaught. Nearly all the western half of Ireland has a rainfall over forty inches. The central plain is wetter than that of England. The wettest districts in the British Islands are: the mountains near the Caledonian Canal, a mountain knot in Argyleshire, the Lake District, the Snowdon massif, a block in Mid-Wales, and the centre of Dartmoor—all with over eighty inches. Snowdon has over one hundred inches annually. Contrasting with these are the counties bordering on the Humber and the Wash and the coastal part of East Anglia. Skye, Lewis, Harris, and the mainland adjacent are notoriously wet and misty. The rains there are often torrential, and the gullies and glens which the floods cut out are too abrupt in slope for much vegetation. The denudation of the open slopes also is very severe, and they fall away in long, bare lines. As a contrast, the east coast plains and valleys from Wick to the Forth are well, but not too well watered, and are under cultivation. Another instructive contrast is between the mountains of Brecknock, on which the rainfall reaches sixty inches, and the plain of Hereford, lying in the lee of them, where it is only about half. While the Snowdon range has over one hundred inches of rain, the strip of coast lying to the north-east of it is within its so-called "rain-shadow" and has about thirty inches, hence its favour as a health resort at certain seasons.

Rain falls pretty uniformly throughout the year, which secures the first essential for tree-growth. Our climate is also a good grass climate, except in some of the driest parts of the east, for grass requires frequent

renewals of surface water and a good supply in its chief growing season of spring and early summer.

The number of days in which rain falls is large. For cereal and fruit crops this is unfavourable. Clouds, mist, lack of sunshine, characterise the climate of the west of Ireland and the north-west coasts and islands of Scotland. That is one chief reason for the neglect of many crops which otherwise would grow splendidly in the warm, moist conditions, on the best of the soils.

In this country, snow is neither heavy enough, nor does it lie long enough to affect vegetation very evidently.

B. **Temperature.** Being situated in the cool temperate zone, the British Isles have distinct winter and summer seasons. Being islands, they escape the extremes of winter and summer temperatures that belong to continental climates. These two facts are reflected in the vegetation. The low soil temperatures of winter account for the prevalence of deciduous plants. There is, however, great variety of type, and no resemblance to the highly xerophytic forms, such as belong to regions like the Russian Steppe.

The average annual temperature is 48° F. The isotherms of summer and winter pursue an extraordinarily dissimilar trend. In *summer* there is an approximation to the lines of latitude, except where seas intervene. There is a falling off in temperature from south to north, and, although this is somewhat counterbalanced by the greater length of the summer days in the north, it is great enough to interfere with the ripening of some crops. Wheat, for instance, is not grown in Scotland north of the Tay. The hottest part is that enclosed by the 62° F. line which sweeps round from north-east Kent to the Severn, then

north-east, taking in the midland counties, to the Wash and the Norfolk coast. Within its boundary lie the most important of the wheat lands. In summer the west coast is cooled by its winds and its adjacent ocean more than the east coast; i.e. places on the east coast have a warmer summer than places on the west coast in the same latitude, e.g. in July, London 64°, Cardiff 62°, South-west Ireland 59°; summer temperature in London is 10° above that in the Shetlands.

In *winter* the intensity of cold increases from west to east, the isotherms running nearly north and south. The line 38° F. cuts round in a shallow curve from near London to Flamborough Head; so, seeing that we have here the warmest summer district, we have in the East Anglian Counties—Lincoln and the Yorkshire Wolds—the most extreme, the most continental area in the country. We shall see later (p. 140) that part of its vegetative covering may be regarded as an extension westwards of the continental Heath and Steppe types. The east coast of Scotland, especially from the Forth to the north-east of Aberdeen, is extremely cold. Temperatures of 44° F. or over are confined to extreme south-west Ireland, and as this in summer does not rise above 60°, we have in it the place of least extreme type. Places having mild winter climate (usually above 42° F.) are —the Cornish Peninsula, Anglesey and West Wales, West Ireland, the Hebrides (where they seem to have little more snow than in Kerry), and some of the sheltered valleys in the north-west Highlands. The difference between the average January temperature of London and that of the Shetlands is only 1° F. The average temperature in the Shetlands (60° N. Lat.) is about equal

to that in Milan (45° N. Lat.); this is explained by the influence of the sea and the sea-winds on the islands.

The following is a very important fact. The isotherms usually given in atlases have been reduced to sea-level conditions; they are, of course, purely theoretical and may be misleading. Wherever the land is elevated, the temperature as shown by such isotherms will be too high. This needs watching, as it is the *actual* temperature which has to be correlated with the vegetation.

It must also be remembered that, in considering temperature in relation to plants, three temperatures have to be observed, namely, that of air in the open, of air in the shade, and—of great importance—of the soil. In the soil, temperature varies with depth. There may be considerable diurnal fluctuations within the uppermost few inches; in this country the soil is not much affected beyond a depth of one foot. During daytime, the temperature of the surface soil is higher than that of the air. At a depth of one foot the soil is generally a little cooler than the air in summer, and warmer in winter. This affects root-growth and root activity profoundly. The vital processes, both of the roots and of the soil bacteria, cannot go on below a certain minimum temperature, and they require a still higher, varying with the individual, for very satisfactory functioning. The minimum in North Temperature Zones in about 41° F., and the optimum 99° F.

C. **Light.** The number of hours of sunshine and the intensity of it, are vital to plants. During summer, the period of vegetative activity, the number of hours of daylight is highest in the north of Britain; the value of this is lessened by the decrease in intensity due

to the oblique direction which the sun's rays pursue. The hours of bright sunshine are lessened by the cloudiness of the north-west.

D. **Topography.** Much depends on the aspect of hill land; the warmer, brighter, southern slopes are more richly clothed than those facing north. Steeper slopes receive the sun's oblique rays more nearly vertically. Deep valleys may at certain seasons receive scarcely any direct sunshine. Mountains may protect vegetation from cold north and east winds, or from very strong winds. Rainfall on two sides of a hill may be very different. Very steep slopes imply thin soils. Narrow valleys are cold at the bottom, owing to the cold down-draught of air from the chilled higher strata, at night. The above are some of the many examples of how the natural configuration of the land affects what grows on it.

2. *Soil: Origin*

The nature of the rocks which are on the surface of the earth's crust affects plant life in various ways, some quite obvious. The geological history of any locality explains in great measure its topography of hill, plain, valley, swamp, etc. The fashion in which a rock crumbles into sand and dust is dictated by its hardness and chemical constitution no less than by climatic factors. In turn, this determines the character of the water which permeates the soil as "soil solutions," and of that which runs off as streams and collects as lakes and pools. Further, it will also decide the rate at which accumulations of débris will be piled up—that is to say, the ultimate depth of the soil. Topography also enters into

this; e.g. steep slopes usually have thin coverings of soil. The depth of soil affects the conservation of water within it, thin soils drying up quickly; a deep soil gives plants plenty of root-run, and safeguards them in times of prolonged drought.

The nature of the rock decides whether its débris should be fine or coarse in character, and this dominates the soil's water capacity, its retentive power and its permeability.

The mineral particles vary very much in size; on that basis they are classed as:

(*a*) Clay particles (below 0·002 mm. in diameter).
(*b*) Fine silt (0·002 to 0·01 mm. in diameter).
(*c*) Silt.
(*d*) Fine sand.
(*e*) Coarse sand.
(*f*) Fine gravel.

The physical character of the soil depends on the proportions in which these are mixed together. In this respect the agriculturist speaks of (*a*) sands, (*b*) clays, (*c*) loams.

Soil is a mixture of (i.) humus, and (ii.) mineral matter.

(i.) The humus is the organic constituent. Its source is the remains of animals and plants, which occur in all stages of disintegration—this disintegration, or decomposition, being due to the activities of soil organisms, chiefly bacteria. Humus is very retentive of moisture, and contains much easily convertible plant food.

(ii.) The mineral particles are derived from the breaking up of the rocks. In cuttings which man has made in the ground, e.g. quarries, there may be seen three horizontal regions. The lowest is the compact rock-mass. Above

this is a layer derived from it, but loose and crumbling; this is the subsoil. On top lies the soil—the humus, plus mineral matter. The latter is in part derived from the subsoil, and in part has been transported thither by various agents.

3. *Types of Sails in the British Isles*

(1) **Clay Soils** offer great resistance to the entrance and passage of water; they can retain a large amount of water once it does obtain entry. The presence of so much water in the soil-pores means a poor supply of air in the soil; this is serious, seeing that not only do the roots of the plants require air, but the soil-bacteria must have it. If certain of these bacteria are not doing their work, unaltered or partially altered humus will tend to collect, and the soil will be "sour."

Again, a water-soaked soil requires much heat to raise its temperature, and spring growth on such soils will be backward. In very dry weather clay soils shrink and crack as they dry, forming very hard clods. In all conditions they are difficult and expensive to cultivate. They are usually poor in calcium carbonate, but hold plenty of other plant food.

(2) **Sandy Soils.** These are well-drained, and may suffer from drought. They are not good surface reservoirs. They are, however, easily heated. They are not rich in plant food.

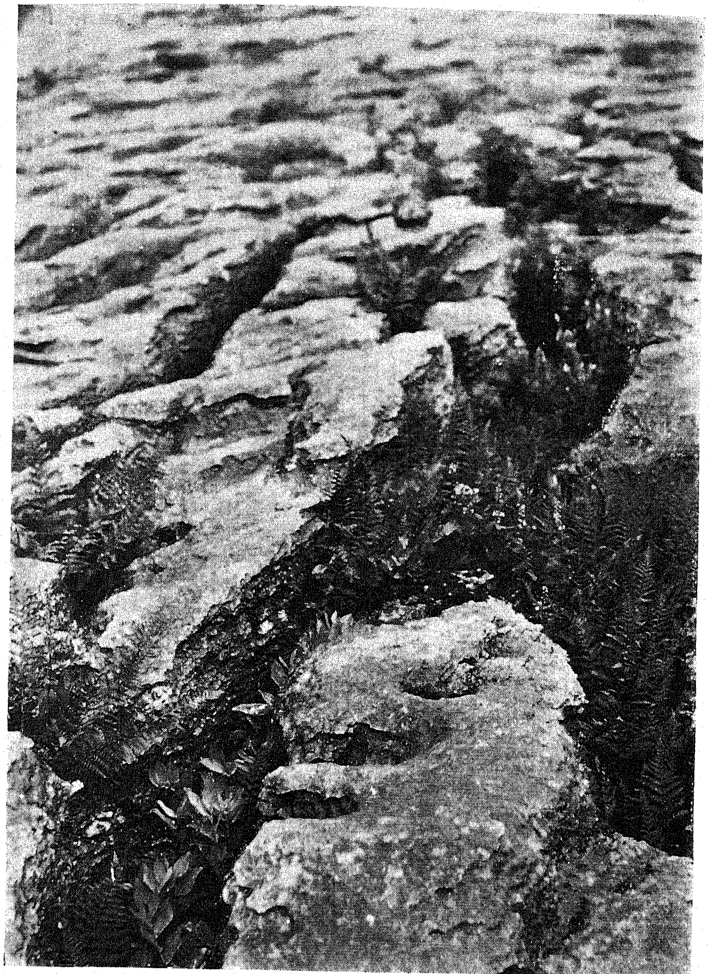
(3) **Calcareous Soils.** These are highly important. The necessity for $CaCO_3$ in soil is being more and more widely recognised by the agriculturist. Calcareous soils are warm, and fairly dry, having abundance of soluble,

useful salts. The soil solution is neutral or alkaline. Bacteria and earthworms can operate well in such soils. Plants which grow only on soils containing a goodly percentage of lime (at least five per cent) are called "calcicoles"; those which seem to avoid lime, "calcifuges." Various theories have been advanced to explain this preference of plants; we cannot enter upon them here. It is clear, however, that rainfall, soil temperature, depth of soil, humus-content, etc., must all be considered in conjunction with the lime-content of the soil.

(4) **Marls** are mixed soils of clay and limestone.

(5) **Loam** is a mixture of clay, sand and organic matter.

(6) **Peat.** There are immense areas of peat in the world, and generous expanses in our own country. National importance should be attached to the problems connected with peat—the causes which give rise to it, research in ways of utilising it, the conversion of peat land into agricultural land. The causes are still much disputed, but it is obvious that peat abounds in regions of low temperature and high rainfall (e.g. in Tundra), and only to small extent in the tropics (e.g. a little in Brazil). Peat is a mass of slowly changing vegetable matter. The series of changes in organic matter which are wrought by bacteria may be regarded as falling into several sections; peat is the result when the bacterial action ceases at the end of the first stage, humus when it goes on to the end of the last. Some reasons given for the premature check are these: that temperatures are too low for bacteria to act, that the surface layers are dried too quickly by winds, that the water present has driven out the oxygen required by bacteria, that calcium carbonate is lacking, and lastly, that poisonous by-products



By courtesy of Albert Wilson

FIG. 4. LIMESTONE "CLINTS": DALTON CRAG

"Cleft" vegetation consisting mainly of Solomon's seal and the rigid shield-fern. *From "The Flora of West Lancashire."*

of bacterial activity accumulate and finally kill off the bacteria themselves. The acidity of peat is the most adverse quality as far as plants are concerned; only very peculiarly adapted xerophytes can endure it. Plant food is very scarce, especially the all-important nitrates, potash and phosphates.

In bogs and on wet peat some plants obtain food in a very unusual way. Whereas the green plant's food is normally inorganic and chemically simple, these plants utilise the more complex organic substances. They are known as insectivorous plants from the fact that they capture and digest insects. In Britain we have examples in the butterwort, the sundew and the bladderwort. The sundew has attractive red leaves which bear sticky tentacles; these close down over flies which touch them, and hold them till they are digested by fluids poured out by glands on the leaves. The pale-yellow rosettes of butterwort have very sticky leaves, inrolled at the edges; they behave much in the same way as those of sundew. The bladderwort lives in pools; it captures its victims in minute bladder-like capsules.

(7) **Fen** is also a mass of slowly decaying plant remains. It differs from peat in being alkaline. It lies over soils containing calcium carbonate.

(8) **Pan.** This is a stratum of very peculiar character, which may form at various depths, near the level of the ground water-table. It generally consists of sand grains cemented together with humus and oxides of iron. As it is excessively hard, and impenetrable to root-growth, its presence is a severe check on vegetation. The soil overlying it has no drainage through it, and no capillary flow from below can get beyond it. It often occurs below

peaty soils, and it may form on arable land if the cultivator practises shallow ploughing as a regular custom. Its origin in nature is a matter of much discussion. Its removal is a matter of necessity if the ground is to be of agricultural value.

4. *Conditions of Soil and Climate required for certain branches of Agriculture*

This seems the most convenient place to outline certain plant requirements. The foregoing paragraphs can be referred to for the British localities in which climatic needs will be met, whilst in the chapters still to come the favouring soils will show themselves.

(1) **Woodland.** The requirements for strong tree-growth are these: (*a*) The soil must yield a large supply of water; this does not necessarily mean that rain must fall frequently throughout the year, for the tree is capable by its long roots of drawing upon deep reserves of water. (*b*) Freedom from very strong or very persistent winds, especially cold winds. The species of tree which is dominant on specific geological formations will be dealt with in these connections. One must always discriminate between natural woods, and woods of man's planting. A natural wood is one that rejuvenates itself without man's interference, young tree-growth arising from natural seeding. Very little natural woodland now exists in England (see p. 165). The counties bordering on the English Channel are very well wooded. Large forests are not common, but small enclosed plantations are numerous throughout England and South Scotland, and it is the rule to find the narrow valley-heads among the hills thick with low tree-growth.

(2) **Grassland.** Perennial grasses, as compared with trees, possess a much smaller transpiration area, and have also a root-system more closely restricted to the top layers of the soil. The drain they make on the soil-water, therefore, is smaller, but that water (apart from renewals due to capillary attraction from lower levels) must be situated near the surface. A fairly frequent and evenly distributed rainfall would secure this. If the grasses die down in winter, there must be plenty of water ready for their spring revival. Long droughts are dangerous to grasses; winds are not particularly so.

Distinction must be drawn between natural grassland and artificial. In the British Isles the land surface has been so altered by man that natural grassland is not common. The strictly stable, natural, grass regions in this country are:

(*a*) The Chalk Downs.

(*b*) The Mountain Limestones.

(*c*) Some of the calcareous boulder clays.

(*d*) Some of the basic igneous rocks.

(*e*) Land flushed freely with fresh water containing mineral plant food.

In various places man has drained marshes and turned them into grass fields; through grazing, etc., heath has been eliminated in favour of pastures; when woods have been cut down grass has replaced them.

The character of grassland is materially altered after being grazed over for several years. It is well trodden; it is manured. Also, the constant cropping, particularly of inflorescences, kills off certain species of plants altogether. In addition to this, man deliberately changes the flora of the grass field by sowing such mixed species as will

ensure various qualities he desires, such as—a good turf, a succession of pasturage throughout the seasons, etc.

Some pasture lands suit sheep; some are better for cattle. Sheep can find subsistence on poorer grassland, on rougher ground, than can cattle and horses. Cattle need more water, and moist meadows with longer, richer grass, suit them, whereas sheep prefer the shorter grass. On wet land sheep are liable to contract certain diseases. When these and climatic facts are borne in mind we understand the prevalence of sheep-farming on the dry Chalk Hills of England, the Yorkshire Pennine Fells, the Southern Uplands of Scotland, and the slopes of some of the Highland Hills; the higher average of sheep over cattle in East Anglia; the higher average of sheep in the east as compared with the west of Scotland; and the preference for cattle rather than sheep in Ireland.

Horse-rearing is successful on moderately dry grass-lands; hence it is carried on in parts of the English Midlands, in Suffolk, north-east Yorkshire, in Upper Lanarkshire and in parts of Ireland.

(3) **Wheat.** This crop makes high demands. Soil must be good in all respects. First of all it must contain enough of the chief plant-foods—nitrogen, lime and phosphates; and as every cropping impoverishes the ground severely, the supply must be constantly renewed. The soil must be capable of retaining moisture, but at the same time be well drained. The quality of the grain depends largely on the texture of the soil; to give a highly nitrogenous sample of wheat, the soil must contain no less than thirty per cent of clay or silt. It is a mistake to say in unqualified fashion that heavy clay-land is good wheat-land; such land is very cold and is too stiff to work economically.

Clay, lightened with lime and sand, is excellent. We have in this country no soil quite so rich, naturally, in nitrogen and humus as the "black soils" of Russia or similar soils in North America. Very valuable are the soils derived from river alluvium, old lake beds, and calcareous glacial clays mixed with sand.

The right kind of weather is no less imperative than is right soil. Wheat has a peculiarly characteristic growth. When just past seedling stage, it gives off near the ground a number of shoots; this is known as "tillering." Each of these rises as a stem bearing, later, its head of grain. The weight of the crop will depend upon the extent of tillering. That in turn is regulated by weather; in late spring and early summer the temperature should be cool and the water supply abundant. Those seasons, then, should be rainy, or a conserved water-supply should be available. When the nature of the winter permits, wheat is sown in autumn; this gives a long period of slow growth during which the buds form in large numbers. The annual rainfall need not be heavy; the chief wheat-growing areas of the world have in most cases an average rainfall of less than thirty inches. A long, rather damp winter is favourable; a wet spring; a dry, hot late summer and early autumn are essential. If the climate is too moist, the crop is more liable to fungoid pests. A sunny climate is necessary for bright, hard grain. Our main wheat-growing regions are East Anglia and the East Midland counties, the best parts of the Yorkshire plain, Tweeddale and the Lothians of Scotland. Ireland and the west coast of England have not sufficient sunshine to ripen grain well. In most of Scotland the season is too short for ripening.

(4) **Barley.** Barley is much more accommodating to

the farmer than wheat. It can thrive in a very wide range of soils and climate. Its ripening period is short, hence it can be grown farther north and at greater elevations than can wheat. "Bright" grain, however, is produced only when it ripens in strong sunshine. Soil must not be too heavy; in England light mixtures of chalk and clay are very successfully used. Barley can, indeed, be grown on soils from which the best has been taken by other crops. In early English times an interesting rota of crops was wheat, barley and fallow. Barley is suited to the eastern English counties, the Yorkshire Plain and Scotland.

(5) **Oats.** This crop also has a wide range. It can endure a low temperature, and it requires less sunshine for ripening than wheat or barley. It is the chief crop of north Scotland, where the cool, moist weather suits it very well. The best soil for it is one with a fair amount of moisture, but not necessarily rich. The acreage under oats is about double of that which is under wheat. The crop is more productive than wheat.

(6) **Potatoes.** Potatoes are of the finest quality and freest from disease when grown in well-drained soil which contains plenty of plant food. The most suitable districts are the well-drained soils of Ireland, the Lancashire–Cheshire plain, the Fen district, and the east of the Scottish Lowlands.

(7) **Turnips** are at their best in light, dry soil. They take an important place in a cultivation rota, not making heavy demands on the soil. Where they are eaten on the ground by sheep the ground is manured for next year's crop. East Anglia and the Scottish farms grow large crops.

(8) **Fruits.** A fair amount of rain is necessary for the

development of foliage and the swelling of fruit. There must be a sunny period at the right time for ripening. Protection must be afforded against east and north-east winds in the blossoming period; winter winds might quite safely be cold, as there is then no danger of loss from leaves, and winter-buds have waterproof coverings protecting them from desiccating winds. Cold winds improve the wood of fruit trees, and help to destroy various pests. The soil in which fruit trees are planted should be rich and well-drained. Various qualities suit different fruit crops.

(9) **Sugar-beet.** Beet sugar is prepared from the swollen underground organ of the sugar-beet plant. It forms a great industry on the Continent, and it is being put to the trial in England. Its soil requirements include a deep medium loam in which lime is present; neither close-textured clay nor porous sands are of any use. Potash salts, phosphates and other fertilisers must be liberally supplied; an application of common salt to the soil increases the yield. Hot and rainless weather in August favours high sugar-content in the plant. Experimental districts in England are Lancashire, Cheshire, the Yorkshire Plain and East Anglia.

(10) **Flax.** Flax is grown in this country for the sake of the fibres. The dry, hot seasons of such a country as India are imperative for a high yield of seed and oil. Fibre flax thrives best in cold climates. It must have deep, well drained, moist soil. Rainfall should be moderate. The "retting" or rotting process is hastened by showery, alternating with frosty, weather. The north-east of Ireland and some parts in the east-Midland counties of England are engaged in flax culture.

CHAPTER IV

CHAPTER IV

THE ROCK SYSTEMS

A VERY bare geological outline of rock systems must be indicated; it should be supplemented through a geological textbook and a good geologically coloured map.

Three main groups of rocks constitute the crust of the earth.

(1) The *rocks* known as *aqueous* or *sedimentary*, have nearly always been laid down in water. They are often stratified. Sometimes their deposition may be traced to the agencies of plants or animals. To this class belong sandstones, shales and limestones.

(2) *Igneous rocks* have been consolidated from intensely hot molten material. Such rocks are unstratified. They are subdivided into two groups according as they have cooled and solidified beneath other layers of rock, or on the surface of the earth's crust. In the first group the molten material is thrust up amongst overlying strata, and hardens into huge bosses or penetrates the already existent beds as vertical *dykes* or horizontal sheets or *sills*. These deeply formed rocks, of which granites and gabbros are examples, have been styled *plutonic*. In the second group the matter welling up from the hot depths succeeds in finding a surface outlet, in volcanoes, fissures, etc. It cools freely and quickly; it has escaped from the

pressure under which the plutonic rocks solidified. Basalt and andesite belong to this group of *volcanic rocks*.

(3) The original form of both aqueous and igneous rocks may be altered in the course of ages owing to the intense heat and the enormous pressures to which they are subjected. For example, unstratified rocks, such as granite, may have a form of stratification impressed on them; they give rise to gneisses, which are more massive in their layers, and schists, which have thin layers. Sandstones may be altered into quartzites and limestone into marble. These altered rocks are known as *metamorphic rocks*.

If the stratified rocks had not been disturbed since their deposition, the sequence would be easy to follow from the oldest at the base up to the newest at the top. This is rarely true for any great depth. The strata have been bent into long folds, tilted, broken, overturned, heaved up, dropped down; their edges stand up sharply as hill peaks or as escarpments; their plane faces slope in many directions. The edges of many buried strata outcrop at the surface, and originate variety in surface soil. It is these outcrops which are plotted on a geological map.

One accepted classification of stratified rocks is this:

CAINOZOIC OR TERTIARY	Recent Pleistocene Pliocene Miocene Oligocene Eocene
MESOZOIC OR SECONDARY	Cretaceous Jurassic Triassic

PALÆOZOIC OR PRIMARY	Permian Carboniferous Devonian and Old-Red Sandstone Silurian Ordovician Cambrian

EOZOIC OR PRECAMBRIAN

There are many sub-divisions of these, some of which may be disregarded; and for our purpose the scheme may be simplified by grouping together some of those named. This grouping will be indicated in the course of the following chapters.

The rocks referred to above constitute what the field geologist terms "the solid geology." He knows, however, that over great areas in the British Isles these rocks will not be at, or even near, the surface, and may not be the soil-forming rocks of these areas. This is due to the fact that our islands form an extensively glaciated region (see p. 137), and are strewn with the loads of clay, sand and gravel which were transported from place to place by the glaciers. So the geologist, and more especially also the ecologist, must supplement the geological map by a "drift" map, which will show the distribution of the glacial deposits.

CHAPTER V

CHAPTER V

CORRELATION OF VEGETATION WITH GEOLOGICAL STRUCTURE: PRE-CAMBRIAN ROCKS

WITH the exception of small exposures of sedimentary and volcanic rocks, the oldest rocks of the British Isles are metamorphic—schists, gneisses and quartzites—which have been pierced extensively by thrusts of granite. Draw a line from Stonehaven, south-west across Scotland and Ireland to Galway. Nearly the whole country to the north-west of it—all the weather-eaten plateaus, the sharp-ridged mountains, the narrow peninsulas, the chains of islands, the massive cliffs — represents the battered remains of that lost Continent which in early ages probably extended far west into the Atlantic. Some of the old rocks are concealed beneath newer formations, but they keep to the surface over most of the Highland area.

The metamorphic rocks break down into soils of varying fertility, often very high. Climate and physiography, however, are dominating factors in this area, probably more so than anywhere else in the British Isles. Level land is of small extent, slopes are steep, the mountains are the highest and the most massive in Britain, the rocks weather slowly and soils are shallow. On the western hills, facing the Atlantic rain-winds, the rock-destruction is indeed rapid, but the débris is rushed down the steeps without a chance of collecting.

Boulder clay and other glacial remains profoundly

modify the contours of the country, filling up valleys, banking up against the hill-sides, constituting terraces, and resting on plateaus even at heights of two thousand feet.

Five of the recognised plant formations inhabit the metamorphic region:

(*a*) The Moor.
(*b*) The Heath.
(*c*) The Arctic-Alpine Grassland.
(*d*) The Mountain-top Detritus.
(*e*) The Chomophyte.

(*a*) **The Moorland.** This is a plant community which owes its stability to its habitat of *deep, acid* peat; to the difficulties of this situation the plants have accommodated themselves, and there they are fairly safe from competitors. The peat of the true moor is always deep (thirty to fifty feet not unknown); it is devoid of lime and of most mineral plant food; it is full of moisture when unbroken; earthworms are absent and most of the beneficial bacteria. It forms most readily where medium or heavy rainfall falls on ill-drained soil, especially if the climate is cold and if the soil lacks lime; all three conditions are unfavourable to bacterial action. The result is a slow rate of alteration of dead organic matter and a gradual accumulation of it. It must be remembered that the peat is a legacy from the past and that its presence must not without due care be taken to indicate a "peat" climate as existing now. Only where it is increasing in thickness is the conclusion justifiable. Generally speaking, the British peat is breaking up and disappearing. The peat "mosses" of the Scottish Highlands show their history written in their sections, and it tells of great

climatic changes. The peat is of post-glacial age. The lowest layers, and also some of the higher, contain Arctic plants. Oscillations of climate have occurred. There are at least two levels within thick deposits at which stumps of forest trees lie thick; the fairly dry conditions required for their growth must have given place time and time again to the stagnation of bogs. Peat forests are found in the deposits of the now treeless Hebrides, and at three thousand feet in the Grampians, far above the present tree-limit for the localities. The present era is one of drainage and consequent peat-degeneration; streams are cutting gullies and undermining their sides; the peat masses as they dry, crack and crumble, then are carried off by wind and water. The wet moor becomes a dry moor, and the dry moor may become heath or grassland.

Wide-spreading moor occupies parts of Caithness, north Sutherland, the north-west corner of Scotland, and the northern Hebrides. Boulder clay underlies most of it. A second wide area is the Moor of Rannoch, a very wet *Sphagnum* moor; a third is in the area of extremely heavy rainfall between Loch Fyne and the Firth of Lorne. Others are scattered on the high plateaus of the Grampians. The metamorphic rocks of western Ireland also have their peat bogs, as, for example, in the desolation of Galway and Mayo. They are the "black" bogs of the hill-sides and the hill-hollows.

The wettest plant-association of the Scottish Moorlands is the bog-moss association (*Sphagnum* association), which includes few plants besides the bog-mosses.

The deer-hair sedge (*Scirpus cæspitosus*) association is the most extensive. In north-west Sutherland and over

the basalts of Skye it covers hundreds of square miles. Along with the *Scirpus* grow *Eriophorum, Erica tetralix*, etc.

The cotton-grass (*Eriophorum*) association exists, but is not so prominent as in Ireland or on the Pennines. A very striking association is that in which the fringe-moss (*Rhacomitrium*) is dominant. A moorland grass association, with the blue grass (*Molinia cærulea*) dominant exists where a sufficient amount of mineral matter is mixed with the peat. The alpine peat-moss association belongs to the high levels; it forms a close carpet of mosses and lichens, broken up by protruding clumps of bilberry, cowberry, crowberry, heather, bearberry, dwarf willow, rushes and sedges—all of lowly growth.

Where drainage has partially dried the peat the proportion of *Ericaceæ* to mosses and rushes increases. A very constant marginal zone to a wet moor is a grass association of mat-grass (*Nardus stricta*).

The moors over the metamorphic rocks of West Ireland are very grassy except in the wettest spots, the chief grass being *Molinia cærulea*. R. Ll. Praeger says of them: "The impression conveyed by the vast mantle of bog in Connemara is that peat-formation is still proceeding steadily over the great driftless rock-floor. While innumerable lakelets fill the hollows yet every gradation may be traced from deep water through *Cladium* and *Phragmites* swamp and *Rhynchospora* bog, to the prevailing *Molinia* moor."

(*b*) **Heath Formation.** The heaths deserve much consideration from botanists; the controlling causes of their existence are far from being fully understood, whilst they occupy so much ground which might be valuable

that their reclamation is economically desirable. Local use of the terms "moor" and "heath" may be misleading. The "moor" of science, the *Hochmoor* of Central Europe, we have already defined. The "heath" of science implies a substratum of peat which is again *acid*, but is *thin*, e.g. with a maximum depth of twelve inches. The underlying soil is sandy or gravelly, and leached of soluble minerals; rainfall must be moderately high. Great heaths cover the poor sands in western Europe from Jutland to northern France.

In our Scottish area, the heath formation is spread over immense distances in the east and the north-east. It is said to be limited eastwards by the line of sixty inches of annual rainfall; it is associated with less deeply dissected mountain blocks, with drier air and sunnier days than are found in the west. The two areas are connected by intermediate stages, and gradations may be gradual. Drier peat-moors with *Calluna* are linked with the wetter heaths of the east.

The formation includes:

(i.) *The Heath Association.*

(ii.) *The Pinewood Association.*

(i.) This constitutes the famous heather-clad "moors" (properly heaths) of Scotland; their gorgeous colouring adorns the valley sides and the lower mountain ridges from Tay to Ness. They are grouse moors. By far the most abundant species of plant is ling (*Calluna vulgaris*), with which grow bilberry, crowberry, cowberry. There are no trees. The "moor" is a xerophytic habitat, exposed to strong winds, strong sunshine, and provided with an unfavourable soil. Its plants are of low stature, and have small, rolled, leathery leaves. The acid peat does not furnish

nitrogen readily. Insectivorous plants, such as sundew and butterwort, are peat plants.

(ii.) There is no doubt but that the Highlands at one time were surprisingly well-wooded. The destruction is due in the first instance to man; the soil thus left unprotected from rain-storms was swept away or denuded of its humus, and recovery was impossible, or, before forest regeneration could take place, heath or grass took possession. Traces of lost forests are very many. At the present time the west is the poorer in woodland: the centre and the east the richer. The strong winds and heavy rains of the west are hostile to the pine and the larch.

Referring to the forests in general, mixed woods prevail up to about nine hundred feet. For about another thousand feet coniferous forests hold their own; the tree limit is lower in the west and on isolated mountain peaks. Scots pine (*Pinus sylvestris*) is the native tree now as in the peat forest times; larch is planted with it and birch is plentiful. Rothiemurchus and adjoining forests in Strathspey, and the Black Wood of Rannoch, south of Loch Rannoch, are relics of the ancient Caledonian forest.

Of constant occurrence in the Highlands are the birchwoods, with both common birch (*Betula tomentosa*) and white birch (*B. alba*). They may be taken as a subassociation of the *Pinus* community, but are classed in the *Types of Vegetation* with the English woodlands as an association within the formation of siliceous soils. They have a definite habitat marked out by altitudinal limits—above the oakwoods, from about one thousand to one thousand eight hundred feet.

Above the moor and heath line a typical high mountain

Photo, W. B. Crump

FIG. 5. COTTON-GRASS MOOR AT WESSENDEN, ON THE PENNINES

On millstone grit: elevation 1000 to 1250 feet. *Eriophorum vaginatum* and *E. angustifolium* dominant, the latter prominent in foreground.

vegetation is present. Many of its members are found on the European Alps, and even more numerously in the Arctic regions; hence the term arctic-alpine has been given to this vegetation. Robert Smith, the pioneer in botanical survey in Britain in 1900, and W. G. Smith more recently, made special surveys of the mountains of northern Perthshire, and in particular of Ben Lawers. Their records are of more than local application, being fairly illustrative of many of the Highland mountains.

Whilst the mountains north-west of Glenmore are mainly gneissic masses, there is more variety amongst the bare rocks of the south-east Highlands, and a closer dependence of the plant-growth on the native rock. For example, there are bands of mica schist which both here and in Ireland crumble down readily into deep fertile soils. Bands of metamorphosed limestone bear their special flora. Glacial clay is confined to the valleys; the morainic sands and gravels lie as terraces along the valley slopes; much more rock is free from drift than in the north-west.

Three alpine formations find homes above the two-thousand-feet line.

(*c*) **Arctic-Alpine Grassland Formation.** Above the tree limit of the Swiss mountains lies the belt of alpine meadows. It is of interest to find that on many of the Scottish mountains grassland is the lowest division of the alpine group of formations. It is a well-drained, well-watered habitat, with a stable plant-covering; grass predominates, but intermixed with it are alpine species from the heights above. It is confined to certain mountains and very frequently to the southern slopes of these.

(*d*) **Formation of Mountain-Top Detritus.** Many miles of mountain top are strewn with the wreckage of splintered rocks. Long screes of sharp-edged flakes, boulders, pockets in which have accumulated the finer particles whirled out of exposed spots by wind or carried downhill by water—these are the make-up of this ungracious habitat. Often the mass of débris is deep, and always it is porous. It supports two types of association. One is an open community of mosses and lichens, together with a few flowering plants. The other is the curious *Rhacomitrium* association, in which the woolly fringe-moss (*R. lanuginosum*) grows as a thick carpet as much as a foot deep. Creeping within its shelter and sending up above it very little of their foliage there thrive in safety the usual alpine species. Any that make bolder attempts at height assume cushion, rosette or mat forms. They may be silenes, potentillas, dwarf willows, viviparous grasses, etc.

(*e*) **Chomophyte Formation.** This inhabits the gullies, the crag-faces, the ledges and the fissures. With unending variety in local conditions of shelter, moisture and soil, it breaks up into very many small societies. Here grow the truly arctic-alpine plants, the sanctuary of the rarest being the Breadalbane Range. They attain their best on strata of chloritic schist. Amongst them are *Gentiana nivalis, Dryas octopetala, Thalictrum alpinum, Erigeron alpinum, Salix herbacea,* the alpine saxifrages, etc.

Cultivation Areas

The broken, rugged landscapes and, in the west, the heavy rainfall are adverse to farming. Cultivation is confined to the valleys and the better of the lower hill

slopes. In the north-west it is practically absent; in the Western Highlands the rainfall favours grass, and pastoral farming till recent times had fair success. On the best hill-land, sheep runs extended even up to three thousand feet. In summer, deer graze on the heights above two thousand feet, on the short alpine grass and the peat vegetation; in winter they come down to the valleys and encroach upon the sheep-pastures. The unwooded, so-called "deer forests" are of immense extent, expecially in the north-west. The high rentals obtainable for these and for grouse moors have led to land being withdrawn from sheep and timber usage. Grazing has been increasing at the expense of mixed farming; cattle have given place to sheep; small holdings have been combined into large. The chief cereal crop is oats.

The very extremity of barrenness is displayed on the Highland mountains of quartzite. Such a hill is Ben Eay, near the head of Loch Maree. It rears its crest in absolute nakedness. So high is the angle of its slopes, so knife-like its ridges, so baleful is its cold glitter in sunshine, so unearthly grey can it be in dullness, that one could not conceive of living things being harboured on it. Yet, down below, within a mile, the September strawberries are ripening in the gardens, and the roadsides by Loch Maree are wooded with pine and birch, beautiful with heather and bracken.

Only a few degrees less desolate than the quartzites are the long monotonous moors of Lewisian gneiss, which border the sea from Cape Wrath to the Sound of Sleat and rise from the sea as the Outer Hebrides. This gneiss is a tough, gnarled rock. Except in the jagged mountains of Harris and North Uist it lies in rounded bosses, repeated

in dull succession for miles. To it is attached intense interest as being the oldest land surface in Europe; since the first-known days of geological time it has lain locked away under the sediments of the sea beneath which it sank. The plant-covering of the gneiss is of the scantiest character. The rock breaks down slowly into loose particles, and the heavy rainfall of these western shores gives them little chance of accumulating to form soil. A little short grass, tufts of heather, a few other poor specimens of moor plants, struggle for existence in the hollows and crevices.

The sediments which buried the gneiss were the Torridon Sandstones, the known thickness of which amounts to eight thousand feet. They are to be found distributed throughout the same area as the gneiss. No feature of a Highland landscape is more overwhelming than the mountain masses into which they are built up. They look as if they literally were *built*—gigantic fortresses. The nearly horizontal strata are laid down tier upon tier; only the narrowest of ledges are exposed; they give, clearly, no friendly shelter for plants. The dark, purplish-red rock breaks apart along its vertical joints, but the fragments decompose into grains with extreme slowness. Hence the soils are shallow; they are very deficient in humus. Very scanty indeed is the covering of heather, grass, etc., which manages to live on the ledges.

A rock formation immeasurably younger than those we have been discussing, appears in Skye, Mull, the smaller islands near them, and in north-east Ireland. Though out of place chronologically, it may usefully be referred to at this point to complete the survey of the Highlands. It comprises volcanic and plutonic rocks,

which originated in Tertiary times. Over all this area and also at least as far north as the Faroe Islands, lava was poured out in floods at widely separated intervals; it consolidated as basalt. Later, amongst the basaltic beds, were thrust quantities of material which solidified underground as huge bosses of acid granophyre or basic gabbro (granophyre and gabbro belong to the plutonic group of rocks, see p. 49; they differ in chemical composition). In the Island of Skye there are remarkable contrasts in geology, in topography and in vegetation, between the basalts of the north and the gabbro mountains (the Cuillins) and the granite mountains (the Red Hills) of the south. The basalts spread out as flat tablelands, which break off in sharp precipices. They yield good soils, and are covered with excellent grassland utilised for sheep-rearing. The crofts and farms are the most flourishing in the island; good hay, potatoes and oats are grown. In the south, short poor grass and not very luxuriant heather are established only for a short distance up the hills, which rise almost direct from sea-level. The upper parts of the hills are either barren ridges as in the Cuillins, or very steep rock-slopes, as in the Red Hills. Spread over the flat land, immediately north of the gabbro, is a great thickness of glacial débris, well mixed clay, sand and pebbles, arranged in countless little hummocks. In the hollows amongst these there collect pools and lakelets of peaty water. The whole district is full of botanical interest—the pools particularly so. The big, white cups of the water-lily come rather as a surprise in these bleak quarters, still more so in the dark pools on the Moor of Rannoch. In some of the morainic ponds, there grows the rare pipe-wort (*Erio-*

caulon septangulare), the only other British station for which is in the west of Ireland (p. 159). In others, the bladderwort, an insectivorous plant, finds plenty of victims. In tiny rock-basins far up on the Cuillins grows the water lobelia. An interesting illustration of climatic influence on growth-form is seen in the gorse and broom as they grow in Skye. Normally both of these plants are highly modified to suit xerophytic conditions; the gorse by the preponderance of woody, thorny tissue over the soft green tissue of leaves; the broom by the reduction of the leaves to minute dimensions. In Skye, the continuously moist air does not favour transpiration and evaporation from plants; the soil always contains plenty of water; there are rarely cold drying winds to desiccate vegetation. To these three factors may be attributed the unusually large size of the leaves of broom, the greater softness and leafiness of the gorse, and the tall habit of growth of both plants.

CHAPTER VI

CHAPTER VI

CORRELATION OF VEGETATION WITH GEOLOGICAL STRUCTURE (*cont.*): CAMBRIAN, ORDOVICIAN AND SILURIAN ROCKS

THESE systems are so uniform in general lithology and in the physical features they give rise to that we do not lose much by grouping them, whereas we gain in simplicity of outline. They mount up to an enormous thickness of strata. They are, in the main, sedimentary, and were piled up in the waters of seas which we know covered at least a great part of the British Isles. Some of the sediments were fine, becoming shales which ages of pressure have turned into hard slates; others, coarser, became sandstones or grits; coarser still, conglomerates; in some districts, at various times, limestone beds were formed. Volcanoes had periods of activity and their ashes and lavas spread over both sea-bed and dry land.

Towards the close of the Silurian period the sea grew shallower and shallower over the area of the British Isles, which became part of the ancient Atlantic Continent. It was not a level continent—this *Caledonia* of the geologist; stupendous forces, slow-acting and irresistible, had rucked up the old metamorphic blocks of northern Scotland, as well as the newer strata, into long folds having a north-east and south-west trend. A

geological map has written upon it plainly the influence which these earth movements have had on the surface distribution of the rocks as we see it now.

The chief exposures are these:

(*a*) The great mountain masses of nearly the whole of Wales, and the lower land of Shropshire, with a continuation into south-east Ireland, where a long granite intrusion has thrust itself up and through as the Leinster ridge, on the flanks of which rest the Ordovician clays.

(*b*) The Lake District Mountains.

(*c*) The wide belt of the Southern Scottish Uplands, running from sea to sea and reappearing in the same line in north-west Ireland.

Generally speaking, the vegetation of these areas is rather restricted and monotonous, owing to the poverty of soils derived from grits and slates, the shallowness which results from the slow weathering of hard, old rocks and the broken, mountainous type of country associated with resistant rocks and great upheavals.

In the *Types of British Vegetation* the authors have identified a certain plant formation as being characteristic of the soils derived from the non-calcareous older rocks, within which they bring the pre-Cambrian, the metamorphic and the Palæozoic sandstones, clays, grits and slates, as well as the volcanic of the same age. This is, indeed, a very mixed assembly, and it is somewhat difficult to find a common character except the general thinness of the soils overlying them. The vegetation is termed the *Plant Formation of Siliceous Soils*, and is not to be confused with one which belongs to sandy soils of later age. It seems rather unfortunate that the term "siliceous" should have been adopted. We may here at least find

it helpful to think of them as the soils of the ancient rocks.

They certainly seem to bear woodland and grassland associations peculiarly their own. The Welsh, English and Irish woodlands are associations of the sessile oak (*Quercus sessiliflora*), along with which the ash grows plentifully in the Lake District.

It may be that *Q. sessiliflora* can exist on soils with less mineral food than the stalked oak (*Q. Robur*), which would explain the absence of the latter from shallow soils and from soils leached by heavy rainfall. The oak-woods disappear above the one-thousand-foot contour now, but there may be a strip above that of wood of the common birch (*Betula tomentosa*). Hawthorn, sloe, gorse, broom, etc., are associates and remain as scrub where woodland degenerates. There is a ground flora of many species—bluebell, wood-sanicle, dog's mercury, wood-sorrel, bracken, grasses, etc.

The grassland is a *Nardus stricta* association, which may have a strong admixture of *Deschampsia flexuosa* (the silver hair-grass). Grassland in which these two grasses are dominant and vigorous, are rough and uneven, owing to the fact that both grasses, through the massing and persistence of their basal parts, form hard, irregular tussocks. Their leaves are characteristic of moor grasses, xerophytic in type; they are narrow, have a hard epidermis, and by the uprolling of their edges they put their transpiring surfaces under cover.

The Wicklow Mountains, with their granite core and summit, illustrate particularly well the power of the drainage factor. For instance, over a certain fairly large area, where the surface rock is all granite, and over which

the rainfall is uniform, there are such differences in the physical features, e.g. slope, that there are several distinct plant associations.

(*a*) On very wet parts, where stagnating water has created one of the high-level "black bogs," the thick, saturated, still increasing peat bears a *Scirpus* (or more rarely *Eriophorum*) association.

(*b*) Where drainage is somewhat better, peat, still thick but not increasing, is covered with *Calluna* moor.

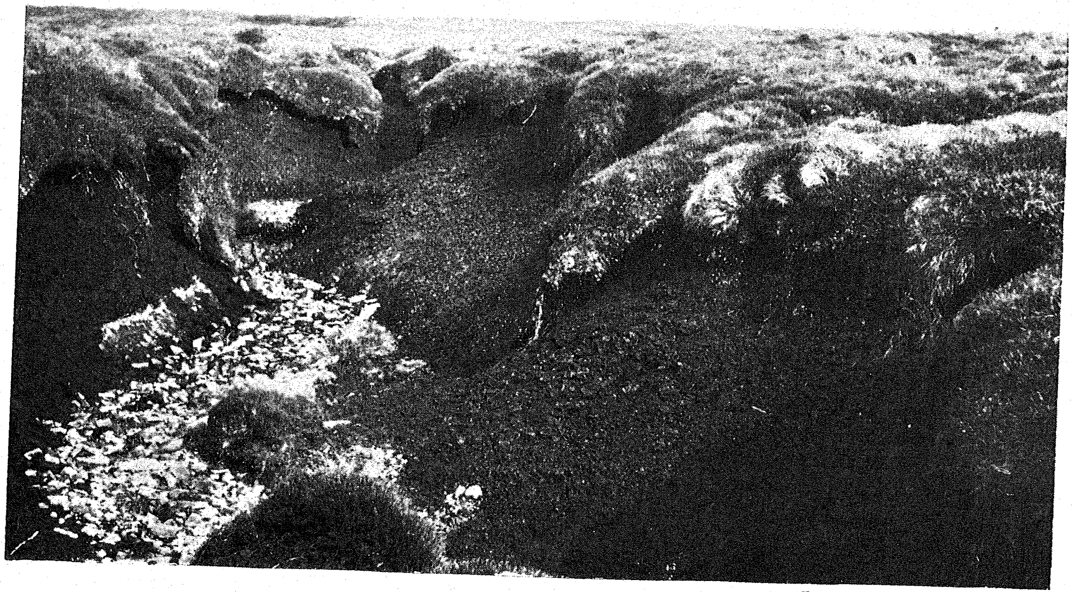
(*c*) At lower levels on the granite the peat is thin and bears a *Nardus* association. A very unique facies is given to this where dominance is assumed by the low-growing gorse, *Ulex Gallii*, whose billowing surface of rounded clumps is brilliantly beautiful in its season.

The Ordovician woods of County Wicklow are pure woods of *Quercus sessiliflora*.

Cultivation Areas

The thin soil characteristic of these older siliceous rocks, coupled with the rugged, elevated character of much of their surface, accounts for their not being under cultivation throughout a great part of their extent.

The Uplands of southern Scotland have a physiognomy which is distinctive and full of interest. Nithsdale separates an eastern portion from a western which possesses more rugged features. The whole is essentially a tableland cut up into slightly separated elevations. In the east, between the low, flat-topped or softly rounded hills, lie hollows as softly rounded. It is a land of freely flowing curves, repeated over many miles; to some eyes its aspect may verge on dull monotony. No woods interfere with



By courtesy of Albert Wilson

FIG. 6. RETROGRESSIVE MOOR ON FAIRSNAPE FELL

Deep peat capped with cotton-grass, bilberry and heather. Broken Millstone Grit in dry bed of gully.
From "The Flora of West Lancashire."

the outlines. The covering is one of close turf, rarely broken by bare rock. Broad Law, in Peebles, is an example of these green, flat summits. It is a noted pastoral country, divided up into large well-managed sheep-farms, with dairy-farming added on the lower slopes. On both sides of the tableland beautiful valleys run far up into the hills by gentle gradients, picturesque with copses, waterfalls, and every charm of the hill-stream. Their glamour colours Border ballad and Border history—"The dowie dens of Yarrow," "Tweed's silver stream," "The lads o' Gala Water." Scott was nurtured among them and loved them; they bred Hogg the Ettrick Shepherd, Thomson, the author of the *Seasons*, Jean Elliot, the authoress of *The Flowers of the Forest*. The ruined "peels," which still stand stark and gaunt on lonely mounds, were the homes of the chiefs of the fighting Border clans.

The soils of the middle and lower courses of the rivers are most fertile; there is much deep alluvium, and, where boulder clay is present, it is well-mixed with the opener sands and gravels. Other rocks, such as Permian, are in places associated with these, and will be treated in their order. The valleys of the Tweed and its tributaries are famous for their excellent farming. The valley crops are oats, barley and turnips.

The tracts of hill-land lying west of the Nith are much wilder and more broken than those on the east; the rivers cut back more sharply; the summits are more generally broken into bare, rocky expanses; peat-mosses and tarns and lakes are much commoner. The scenery bears some resemblance to the quieter parts of the Perthshire Highlands. Three massive thrusts of granite break through the sedimentary rocks—Mount Merrick,

Cairnsmoor of Fleet and Criffel (on the coast). Much of this hill-land is naturally lost as far as farming is concerned. There are sheep on the higher slopes, cattle and horses on the lower, particularly in Lanarkshire and Ayrshire.

The Mourne Mountains, which are the Irish continuation of the Scottish Uplands, form one of the chief sheep-grazing areas of Ireland.

There is much bare rock on the steep mountains of the Lake District. The moist climate favours a beautiful growth of trees on the glacial soils of the valleys and lower slopes, with luxuriant undergrowth of mosses and bracken. The climate is too wet for cereals; the farming is mainly concerned with sheep and cattle rearing.

The Welsh hills are partially grass-covered. The sheep-rearing industry is an old one, and a noted one. Pembroke and Anglesey are famous for cattle.

CHAPTER VII

the outlines. The covering is one of close turf, rarely broken by bare rock. Broad Law, in Peebles, is an example of these green, flat summits. It is a noted pastoral country, divided up into large well-managed sheep-farms, with dairy-farming added on the lower slopes. On both sides of the tableland beautiful valleys run far up into the hills by gentle gradients, picturesque with copses, waterfalls, and every charm of the hill-stream. Their glamour colours Border ballad and Border history—"The dowie dens of Yarrow," "Tweed's silver stream," "The lads o' Gala Water." Scott was nurtured among them and loved them; they bred Hogg the Ettrick Shepherd, Thomson, the author of the *Seasons*, Jean Elliot, the authoress of *The Flowers of the Forest*. The ruined "peels," which still stand stark and gaunt on lonely mounds, were the homes of the chiefs of the fighting Border clans.

The soils of the middle and lower courses of the rivers are most fertile; there is much deep alluvium, and, where boulder clay is present, it is well-mixed with the opener sands and gravels. Other rocks, such as Permian, are in places associated with these, and will be treated in their order. The valleys of the Tweed and its tributaries are famous for their excellent farming. The valley crops are oats, barley and turnips.

The tracts of hill-land lying west of the Nith are much wilder and more broken than those on the east; the rivers cut back more sharply; the summits are more generally broken into bare, rocky expanses; peat-mosses and tarns and lakes are much commoner. The scenery bears some resemblance to the quieter parts of the Perthshire Highlands. Three massive thrusts of granite break through the sedimentary rocks—Mount Merrick,

Cairnsmoor of Fleet and Criffel (on the coast). Much of this hill-land is naturally lost as far as farming is concerned. There are sheep on the higher slopes, cattle and horses on the lower, particularly in Lanarkshire and Ayrshire.

The Mourne Mountains, which are the Irish continuation of the Scottish Uplands, form one of the chief sheep-grazing areas of Ireland.

There is much bare rock on the steep mountains of the Lake District. The moist climate favours a beautiful growth of trees on the glacial soils of the valleys and lower slopes, with luxuriant undergrowth of mosses and bracken. The climate is too wet for cereals; the farming is mainly concerned with sheep and cattle rearing.

The Welsh hills are partially grass-covered. The sheep-rearing industry is an old one, and a noted one. Pembroke and Anglesey are famous for cattle.

CHAPTER VII

F

CHAPTER VII

CORRELATION OF VEGETATION WITH GEOLOGICAL STRUCTURE (*cont.*): DEVONIAN AND OLD RED SANDSTONE ROCKS

THE Caledonian land had been born with many convulsions; we see in the Scottish relics of it how its rocks had been crushed, driven up into folds, thrust along in sheets for many miles. Volcanoes broke out amongst the general disturbance: the land lay under burning suns; the mountain peaks broke down in flakes and splinters; the débris collected in broad-based cones at the foot of the hills, or was spread broadcast by torrential rains or desert winds. Rivers bore sand and silt to settle in sheets of water—wide arms of the sea or lakes. We can even now hazard an opinion as to the locality of some of these circumscribed waters. Their sandy bottoms, enclosing fish remains, now constitute our Old Red Sandstone series of rocks. They are yellow, red or brown sandstones, marls, conglomerates, and volcanic ashes and lavas. They are, from the point of view of their vegetation, probably the most important rocks in the country. Partly owing to the presence of volcanic matter they furnish plentiful and quickly renewed plant food; they disintegrate readily and produce deep loams which can be cultivated easily; as we shall see, they are surface rocks in level country with favourable climate.

There are five chief areas of Old Red Sandstone in the British Isles.

(i.) The Devonian series of Devon and Cornwall differed from the others in being chiefly marine; they were laid down in the sea which crept up to the southern edge of the Continent. Granite obtruded itself amongst them at a later date. Dartmoor is a wild heather-clad granite upland; its deeply cut valleys are wooded; the soils are varied, but not highly fertile except where alluvium has gathered. North Devon has much open heather and gorse land. The climate is too wet for wheat. Many cattle are reared, and butter and cheese are noted products. The drier eastern valleys contain extensive orchards.

(ii.) Old Red Sandstone is the floor of the valley of the lower Severn, and of the Teme in Hereford, and rises to mountain height in the Beacons of Brecknock. It is excellent soil for fruit, e.g. hops in Gloucester, Worcester and Hereford, apples, pears and plums universally. It is the foundation of some of the finest farm-land in the British Isles. In Hereford noted permanent pastures lie on its sandstones and marls. The "Cornstones" are similar beds, but contain bands of limestone; they are specially valued for corn crops. The mountain tracts are bleak and barren.

(iii.) The limits of the lake which covered at least southern and central Scotland, as well as its relation to the Welsh lake, are not known. Its volcanoes must have been extremely active; their lavas in places are piled up to a thickness of six thousand feet. The Cheviot Hills are within this Old Red area; they are built up of sandstones, marls, lavas, volcanic ashes and granite. The close fine turf which covers them is first-grade sheep

pasture. Roxburgh, Berwick and the Lothians have some of the finest farms in the world; much of their surface rock is Old Red Sandstone. In the Lothians there is much glacial drift, ground down from Old Red Sandstone, and it forms the basis of first-class soil. It contains volcanic constituents. The comparatively dry, bright atmosphere also suits crops. Wheat, fine strains of barley, oats, turnips, and, notably, potatoes are grown. Patches of the Old Red formation lie in the Central Plain of Scotland, along the down-throw edge of the southern boundary fault. South-east of the boundary line of the Highlands (p. 55) a strip of Old Red Sandstone, twenty-five miles wide at its widest, extends from Forfar to Dumbarton. The broad fertile valley of Strathmore and the noted Carse of Gowrie are parts of it. It is famous for its fine fruit, especially raspberries and strawberries, and its heavy crops of cereals. The drainage from the volcanic hills of the Sidlaws and the Ochils brings material to enrich the Lowland soil, some of which is altered glacial deposits.

From the rock on which Stirling Castle stands one may look down in early autumn on one of the fairest country-sides in Scotland. As far as the eye can see it may rest on yellow harvest fields—wheat, barley, oats. Gliding like a snake in sinuous coils, the Forth slips through the plain, which, to some extent at least, is alluvium of its own making. With such evidence of abundant return for skilful husbandry one finds it easy to believe the old saying that "A link in the Forth is worth a kingdom in the North."

The soil history, so to speak, of this far-stretching "Carse" of the Forth is an interesting one. Round the

head of the estuary run the remnants of three terraces, or raised beaches, which were in turn the beds of the estuary—but are now one hundred, fifty, and twenty-five feet above its present level. Their beds of sands, muds, shells, etc., form the basis of the soils of the Carse. The Forth itself has added much which it has brought down from the hills. Such soil would be compounded of many ingredients. In the fourteenth and fifteenth centuries, however, Stirling and Falkirk had a goodly share of bogs and pools resting on these soils. It has been by long-continued industry that the present agricultural prosperity has been attained. So highly skilled is the farming along the Firth of Forth, so scientific, that scarcely anywhere else in the world is the crop yield per acre equal to that of the farms of the Lothians and Stirling.

(iv.) All round the north-east coast of Scotland occur patches of Old Red Sandstone; they constitute the surface rock of much of Caithness, the land bordering the Moray Firth, and the Orkney and Shetland Islands. They are level tracts and highly farmed. Root crops and barley do well as far north as Caithness.

(v.) Standing up from the central floor of Ireland are fragments of anticlines (upfolds). Their cores are Silurian, their flanks are Old Red Sandstone; as heather-clad hills they rise from grassy or boggy plains of limestone and drift.

Cork and Kerry form a region of numerous parallel ridges separated by deep valleys, running from west to east. The ridges are Old Red Sandstone, the valleys contain Carboniferous strata. This system of anticlines and synclines (downfolds) was formed in post-Devonian times.

Man has completely taken agricultural possession of the Old Red Sandstone country, except where it is mountainous. Hence natural vegetation is scarce. It would be classed as part of the formation of siliceous soils. The sessile oak association (p. 71) is extensively developed on the lower slopes of the Kerry mountains. The woods round Killarney are the British home of the strawberry-tree (*Arbutus Unedo*) (p. 159).

On the higher parts of the Irish mountains there is much poor moorland and bare rock.

CHAPTER VIII

CHAPTER VIII

CORRELATION OF VEGETATION WITH GEOLOGICAL STRUCTURE (*cont.*): CARBONIFEROUS ROCKS

For our present purpose it is enough to distinguish between three divisions of the Carboniferous System—(*a*) Limestone, (*b*) Millstone Grit, (*c*) Coal measures.

(*a*) *Limestone*

Seas began to encroach on the Caledonian land; they crept over Ireland, over much of western and central England; their waters covered parts of central Europe. Somewhere across northern Scotland ran the retreating shore-line of the old Continent, and between it and the line of our Cheviots was a shallower sea than what lay farther south. On the slowly sinking bed of the fairly deep southern sea, the limestone remains of corals, sea-lilies, etc., settled and consolidated in course of time as limestone rocks. The shallower sea was filled with shales and sandstones—deposits brought down from the Continent. Elevated now as hills, tablelands and plains, the limestone is of great importance in England. Its greatest known thickness in England is six thousand feet. It forms a band across Gloucester, from east to west; it is exposed in beautiful sections in the Bristol Gorge; the Mendip Hills are built of it; it crops out both in North and South Wales; it lies as the great platform on which rest the higher beds of the

Pennine Chain, from the Peak to the Scottish Border. It thins out almost beyond recognition in southern Scotland (the bed of the shallow sea). The whole central plain of Ireland has a floor of limestone, and strips of it are marginal to the narrow sea-lochs of south-west Ireland. Some of it is left upstanding as mountain form in the fine range of Ben Bulben in Sligo, with its sheer cliff outline.

In the *Types of Vegetation* there is described a *Plant Formation of Calcareous Soils*. Its sub-formations are (*a*) that of the older calcareous rock, (*b*) that of the chalk. It is with (*a*) that we are dealing now. The vicinity of Ingleborough provides excellent centres whence short excursions may be made and in the course of these a fairly comprehensive and accurate idea may be gained of the plant-growth on the Pennine rocks—ranging from the underlying Silurians, up to the mountain cap of Millstone Grit.

Woods are met with up to about one thousand feet; they are usually much altered by man's interference—by cutting down and grazing. The ash-association (*Fraxinus excelsior*) is the calcareous type. The commonest tree associates are wych elm and hawthorn. Shrub and ground flora are richly assorted within the woods; big beds of wood-garlic and lesser celandine fill the wet places, dog's mercury where it is drier, and wood-sage where it is drier still.

Shrubs persist above the limit of the woods. You may see solitary hawthorn bushes breasting the gales on the grassy hill-side, or hanging on to the face of the scars, deeply rooted in the crevices. Or you may find hazel-copses so thick that you cannot push your way through

them. You may find holly, bird-cherry, dogwood, guelder-rose, blackthorn, ivy, honeysuckle, mountain-ash and yew.

Free of the woods and scrub, you may climb grassy slopes where the soil is scant and the turf thin, the grass short and its associates few. You may strike more level ground where soil lies in greater quantity and you walk over deeper, springier turf. The dominant grass on limestone is the sheep's fescue grass, (*Festuca ovina*). You will not be likely to find amongst it bracken, gorse, broom, foxglove, or members of the *Ericaceæ;* these are more or less pronounced calcifuges. But there may be the yellow mountain pansy, the lesser burnet, the rock-rose, thyme, lady's fingers, the hoary plantain, etc.

No matter how heavy the rainfall, these upper limestone heights are remarkably dry on the surface. Moisture lies only for a short time on the rocks; it soaks quickly through them, or disappears down the many pot-holes. A network of underground drainage channels is set up; the water is collected into streams which reappear at the surface as springs or even fair-sized rivers, at the level of the junction of the limestone with impervious, older, underlying rocks. It is easy to trace along the hillside this line of "spring" level, by the fresher, taller plant-growth which commences just there.

The dry limestone pastures, with short grass, are well adapted to sheep.

A most unusual form of rock-weathering is seen on the Yorkshire hills, as well as in west Connaught; the limestone lies absolutely bare of soil for miles, and as level as a table. It is a regularly jointed rock, and two systems of joints strike at right angles to the free level surface and to each other. Under the action of the weather

the joints widen and fissures many feet in depth are opened up—the whole a patterned surface of blocks and chasms. In Yorkshire these pavements are called "clints." Ecologically, they are interesting in two ways: (*a*) for the "chasmophyte" vegetation, (*b*) for the colonisation problems.

(*a*) Limestone is readily dissolved by water containing CO_2, hence the fissures. Any soil which might have originated on the exposed surface would probably be either drained away or blown away as it formed. In the clefts, some of it lies, and a distinct "cleft" flora comes into existence. It is fresh and beautiful in its sheltered home. In Yorkshire it includes ferns and mosses, geraniums (*Geranium Robertianum* and *G. sanguineum*), wood-sorrel, dog's mercury, ivy and even shrubs, such as hazel and hawthorn. An even more luxuriant flora rejoices in the warmer, moister air of the fissured limestone pavements of Clare and Galway; here, however, probably due to strong wind action, trees do not establish themselves.

(*b*) Here are two instances of different phases in the colonisation of "clints." One is to be seen on a low flat hill, having a "pavement" summit; it is fringed with dense hazel scrub, which reaches and is beginning to climb over the edge of the pavement. At one end it is well over, and has formed a bit of scenery of charming variety. The clefts are full of plants and are being filled up to surface level. Grass covers some of the flat rock, and certain plants rooted alongside such slabs send flat sheets of prostrate branches over them. In autumn the place is brilliant with the variety of berries on the shrubs mentioned above.

The second instance is a "climax" phase; a closed woodland has succeeded in reaching maturity on clints which are in a more sheltered situation than usual. There, level clints and clefts alike are disguised with luxuriant vegetation. The well-grown ashwood shelters shrubs, herbaceous rarities, luxuriant mosses and ferns.

In a few places in Yorkshire there are rather remarkable little woods of yew. They are established well up on the crags, on exposed screes, and on the very face of the scars, from the cracks in which old, gnarled, mis-shapen trees jut out and spread a flattened outline close to the rock.

Yew and juniper both frequent the west of Ireland limestones.

Another kind of sequence can be followed where a valley cuts down into the Silurians, on the edges of which the mountain limestone rests. On one interesting hill, the lower siliceous Silurian slopes are clothed in grass, bracken and heather. Climb beyond the junction with the limestone, and you are amongst low-growing juniper. Climb still higher to the clints above and you again find heather, on peat, where, *a priori*, no heather ought to be, i.e. on soil overlying limestone. The most likely explanation is that the glacier which crossed this mountain carried detritus of grit and sandstone which the water from the melting ice deposited in the hollows where the heather now grows. Any intermixed limestone would be removed by leaching and a soil of heather type would be left.

The limestone of the Irish plain is thickly masked by glacial drift which has also high lime-content. The best of the Irish grassland occurs on these glacial loams. In

places water-logged limestone is a basis for thick wet peat. Some of the limestone is drift-free; some of the drift is covered with bog. These are the "red" bogs of the level lands (cf. "black," p. 72); they are deep, convex as to surface, and their plants include heather, bog-moss, cotton-grass, etc.

R. Ll. Praeger points out the striking contrasts afforded in the west of Ireland between the calcicole aspect of the limestones and the calcifuge of the gneisses, granites, etc., which lie adjacent. There are not wanting the customary instances of wanderers from one community to the other, but in general the transition is abrupt.

On the limestone plateau of Bulben, and also on pavements near sea-level, there is a most extraordinary gathering of Alpine plants. The spring gentian (*Gentiana verna*), restricted in Switzerland to the higher Alps, is here in full beauty by the sea. So is the mountain avens (*Dryas octopetala*). Many rare alpines are limited to this as the only, or as one of the few British stations.

Hazel scrub is common on the Irish limestones.

(*b*) + (*c*) *Millstone Grit and Coal Measures*

Lithologically these divisions may be regarded as, on the whole, "siliceous" in the sense of the ecologist. The Millstone Grit consists of coarse sandstone with some interbedded shales; the Coal Measures are a great series of alternating beds of shale, sandstone, coal, and a little limestone. In bulk sandstone predominates. In part of the North Pennine area, notably in Wensleydale, a well-marked series intervenes between (*b*) and (*c*). This is the Yoredale series of shales, massive sandstones and prominent, (in weathering) thick beds of limestone, which

latter give a distinctive fertility to the soils washed down from Yoredales into the valleys.

Before the rocks of this period were laid down, there had been a great emergence of land from the Carboniferous ocean. The Grit was a delta or shore formation; the Coal Measures piled up on an oscillating surface which was sometimes a swamp. Towards the close of the period and after it, great foldings and crust-breaks crossed Britain in two directions. The "Armorican" east and west ridges of the first still stand as the mountains of Kerry and Cork, having Old Red Sandstone as ridges and Carboniferous in the hollows; they are indicated in the parallel outcrops of the same rocks on the South Wales coast; no doubt these folded strata lie buried under the Secondary strata of south-east England; they reappear in northern France. The second axis of uplift was almost at right angles to the first. The Pennines were pushed up as a single great anticlinal fold in their southern part; in the north, great faults on three sides—north, west and south—broke up the land and left upstanding a central mass against which subsequent folds were pushed up. Heavy denudation of the range, or plateau, followed, and now we find the Millstone Grit as great unbroken expanses in Derbyshire and extending north to Craven, but beyond that only as cappings for such hills as Ingleborough. From above these highlands all the Coal-measures have disappeared; they lie farther down the mountain flanks and stray on to the lowlands.

The Coal-measures of Scotland occupy mainly the central trough valley; they include beds of volcanic ash and lava. The Grit is but slightly represented in Scotland.

From Ireland the Coal Measures have been nearly all

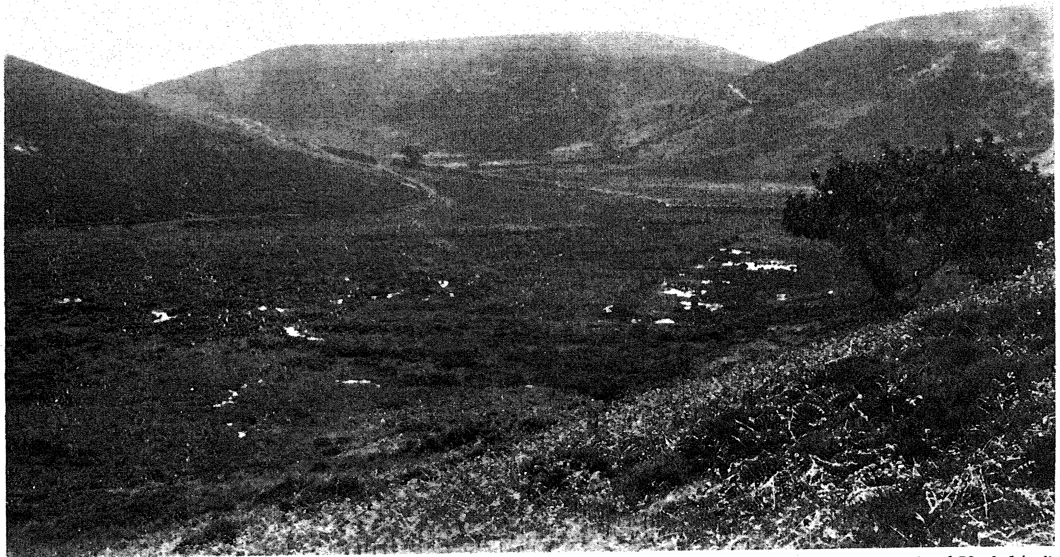
removed by denudation. The Grit, too, is absent, except for parts of isolated hills, which are distributed fringe-like round the limestone plain, e.g. the Galty, Slieve Bloom and Slieve League Mountains.

The range of vegetation on this great series of rocks is most extensive, bearing very clear relationship to drainage and to altitude.

(1) **Woodland** is of the sessile oak type (p. 71), and displays no peculiar features. It ascends in the Pennines, keeping well to the valleys, to about nine hundred feet; above this it may shade off into birch thicket. Higher than this still, on the moorland edge, there flourish plantations of Scots pine, often with accompanying larch and spruce, e.g. on Barden Moor near the Wharfe, at one thousand three hundred feet. They seem to favour fairly good drainage and humus soil.

Anyone who walks by the moor road from Eastby, across the watershed into Wharfedale, may see a wonderful contrast in vegetation. From the pine plantations he passes to the edge of the heather and grass moors of Barden, then dips into a well-wooded valley. This part of Wharfedale is charming in its delicate spring colouring, and gorgeous in its autumn beauty. The walk along the river, from Barden Tower to Bolton Abbey, runs at the foot of steep banks. In spring they are blue with sheets of hyacinth, toned with the intermingled green of pale young grass. In the wider, more open reaches, are stately beech-trees; in the shelter of the valley they keep their foliage till late in the season, and pass from shade to shade of an autumn brilliance which is literally flame-like.

The lowland woods of the Coal Measures, which are interspersed amongst the cultivated land, are mixed



By courtesy of Frank Elgee, from "Eastern Moorlands of Yorkshire"

FIG. 7. MOSS SWANG: GLACIAL OVERFLOW CHANNEL

The floor of the valley is peat with *Calluna-Eriophorum* vegetation. On the slopes, *Pteris* and *Quercus-Betula* scrub.

woods with many planted species; the ground is usually wetter than in the upland woods, and the ground flora more varied. An interesting feature of the northern moors is the "gill" wood, which creeps high up into the heart of the moor, within the shelter of the gills or narrow stream cuttings. The trees in the gill woods are low and crowded; amongst them may be birch, hawthorn, rowan, holly, willow.

(2) **Grassland.** Where the siliceous surface of the Pennine hills is fairly dry the grassland is composed chiefly of mat-grass (*Nardus stricta*); where water lodges even very plentifully the dominant grass is the purple moor-grass (*Molinia cærulea*).

(3) **Moorland.** This varies very greatly and includes examples of the following types of moor: (*a*) bog-moss, (*b*) cotton-grass, (*c*) bilberry, (*d*) heather, (*e*) grass-heath.

(*a*) The bog-moss is a soaking wet moor, chiefly built up from *Sphagnum*. *Sphagnum* grows quickly, the new growth being superposed on the dead, rotting, older parts, the whole sucking in water, both from below and above.

Amongst the mosses grow sundew, butterwort, marsh andromeda, bog-asphodel.

There is only one small moss of this kind on the Pennines, at the head of Balderdale.

(*b*) Cotton-grass moor or "moss" is distributed widely over the Yorkshire Pennines, e.g. near Huddersfield, and between Nidderdale and Wharfedale. Its dominant is *Eriophorum*, whose associates are few, chiefly bilberry, crowberry, cloudberry. It is a very wet moor, usually lying on peat between five and fifteen feet thick. Dr. W. G. Smith says of it: "An area such as this, covered almost entirely with cotton-grass, is dreary in the extreme.

The peat is rarely less than five feet in depth. The rainfall is high and frequent. In the wet season, the moor is a soaking mass, with small pools between the tufts of cotton-grass, and soft dangerous peat-banks fringing the numerous watercourses."

(c) In this the dominant plant is bilberry (*Vaccinium myrtillus*). It belongs to the drier habitats, such as the dry hill-tops and part of the plateau in Derbyshire. It is far from being a pure association, having mixed into it a great deal of heather, cowberry, etc. If a cotton-grass moor is drained the *Eriphorum* disappears, and is replaced by *Vaccinium*. Continued and more severe drainage brings about complete disintegration of the *Vaccinium* moor, the peat being broken up and carried away.

Wide dreary miles of peat moorland are to be met with on the Pennines, moors whose dreariness is intensified by the fact that they are obviously breaking up. Once drainage gets a good start, a moor goes to pieces rather rapidly. A surface network of channels opens when the rains are heavy; one or two torrential storms, ploughing into the slopes, will cut deep into the peat. As soft, blackish-brown pulp it is scooped out and whirled away, deep gullies being left behind. Repetition of this cuts up the surface more and more widely, until the areas of peat between the channels become mere isolated hummocks. These become undermined, and by further rainwash diminish until they disappear. In dry weather also the destruction goes on. The peat mud dries to dust, which is borne off by winds. Anyone who gets caught on one of these abodes of destruction during a thunderstorm will find out the joylessness of the shelter afforded by the banks of a "moss hag."

(*d*) There is also a great deal of *Calluna* moor on the Pennines, particularly on the eastern side. It is a better-drained moor, on shallower peat than the cotton-grass moor. The periodical firing of such moors renews the young shoots of the heather, in the interests of grouse and sheep.

(*e*) Grass-heath is a mixed vegetation in which *Calluna* and some of the grasses are co-dominants. The grasses and heaths of the elevated moors, although growing often on wet or very wet moors, are yet xerophytic in form. The *Ericaceæ* possess small, hard, rolled leaves, evergreen except in bilberry; the grass leaves are capable of rolling together when wilting threatens.

(4) **Cultivated land.** This comprises the level land of the Coal Measures, as well as the valleys and the lower hill-slopes. Much of the plain is now spoilt for agriculture. For many miles beyond the mining and manufacturing centres the effects of smoke on the plant-life can be detected; farming is not very high grade; farms are small; cultivation is often on the market-garden scale. In many of the dales the farming is very good; the soil is a mixture of the sands, shales and limestones from the hills above, together with altered glacial drift and river alluvium. There are satisfactory crops of cereals; in Nidderdale, wheat is grown as high up as seven hundred feet, but it is not a common dale-crop; Wensleydale is noted for dairy-farming, and grows a good deal of oats and barley. Enclosed pasture fields, stone-walled, extend high up the hill-sides; sheep are numerous. There are interesting local histories of the "intake" lands, wrested from moorland by the dale farmers. Some unfortunately have been allowed the short time of neglect which is sufficient

for them to revert to moor. Reclamation demands much labour and expense—it may involve drainage, manuring with lime and addition of plant food, such as phosphates, and of inorganic matter to mix with the peat. With the Pennine "intakes" may be compared the reclamation of heaths in East Prussia. There the barren sandy land is manured in the first instance by sowing lupins and ploughing in the green crop. There are cases in which the soil is devoid of the special bacteria upon which leguminous crops are dependent, and it has to be inoculated by bringing soil from an infected field. The ground enriched by the nitrates of the decaying green manure, is then manured in the ordinary way and bears good crops.

In Jutland over three hundred square miles of barren heath have been reclaimed. The iron "pan" underlying the poor sandy soil is penetrated by ploughing or trenching, and pine and spruce are planted. Or, where the ground is more promising, after ploughing, the land is left for a year or two and then "manured" with marl. After that, rye is sown and in succession potatoes, oats and grass.

The rugged and often elevated character of our moor and heathland increases the difficulties of reclaiming it; but it is possible to do more than is being attempted.

The extensive Irish plain, having chiefly limestone as a surface rock, is of varying fertility, and is cultivated to varying degrees. The mildness and dampness of its climate, and particularly the low number of sunny days, must be remembered. What the land principally requires is drainage; the quality of the soil, which often has high lime-content, could be put to good use. The greatest crop is potatoes, grown where the land has been drained.

Cereals—oats and barley—are cultivated on the drier and more hilly parts, in the counties Tipperary and Limerick. The forests which at one time covered much of the plain are gone; its possibility of wealth is in its excellent grass. Horses and cattle are numerous, but not sheep, for which it is too damp.

The south-west of Ireland — Cork and Kerry — is extremely beautiful. The long anticlinal ridges of sandstone are bold in form and of fine reddish colouring in the bare upper slopes. The lower slopes are luxuriantly wooded. The synclinal valleys, having soils containing plenty of lime, well-sheltered, never exposed to low temperatures, and never within risk of drought, are real homes of beauty. The richly abundant growth of the south of Europe is here, and also some of the very species that are native to it.

CHAPTER IX

CHAPTER IX

CORRELATION OF VEGETATION WITH GEOLOGICAL STRUCTURE (*cont.*): PERMIAN AND TRIASSIC ROCKS

THESE may be taken together, seeing that they have so many characters in common, and that in Britain one follows the other without marked break, although one is classed as Palæozoic and the other as Mesozoic. They are undoubtedly rocks which were deposited in desert conditions. They consist of sandstones, marls, magnesian limestones (i.e. double carbonates of lime and magnesia); amongst them are deposits of salts such as would be left when inland lakes or arms of the sea dried up. It may be remarked that the two Systems are sometimes referred to as New Red Sandstone; that term will not be used in this book.

The largest exposure of Permian in England is that which extends from Nottingham northwards as a narrow belt to Tynemouth, between the Carboniferous beds on the west and the Triassic on the east. In its northern and wider part it consists of magnesian limestone. In the centre of Yorkshire this is the foundation of excellent farm land. It yields a reddish-brown soil, light enough to be easily worked, and to be heated quickly; hence early crops. The pastures also are of high quality and early maturity. The woodlands resemble those of the Mountain Limestone in the prevalence of ash, but differ in the common admixture of beech. Hazel again appears

very often. In the planted woods, the conditions are so favourable that almost any deciduous tree will grow. The Permian hedgerows are peculiarly rich in small trees, shrubs, and climbers.

The Permian sandstones are scattered in smaller areas. The east of Devonshire is Permian, from which a tongue of the sandstone strikes into the centre of the country as the Vale of Crediton. The soils here are light and sandy, and suit fruit cultivation, which is favoured also by the high temperatures and the freedom from very cold winds. There is a little Permian in Warwickshire, in Shropshire, and adjacent to the Cheshire Trias near Stockport. From Kirkby Stephen a narrow band passes northwards to the plain of the Eden; this, the Penrith Sandstone, is almost wholly covered with boulder clay. The Permian outcrops of Dumfries will be taken along with the Triassic.

A very much larger extent of the Triassic beds occurs as surface rock in England. There is a broad zone of them in the Midlands, including the counties of Warwick, Stafford, Leicester, Nottingham, South Derby, and part of Shropshire. This is continued northwards as two bands, one on each side of the Pennines. The western belt runs from Nottingham, north to the mouth of the Tees as a narrow, shallow crescent. Its surface continuation is lost under the recent alluvial and other deposits in North Derbyshire and in South Yorkshire.

The eastern prolongation forms the Cheshire Plain, a wide sea-margin in Lancashire as far north as Morecambe Bay, the coast from Barrow to St. Bees, the flat land round the head of the Solway, and, in Dumfriesshire, one large area in Mid-Annandale and two in Nithsdale.

In a direction south-west from the central region, Triassic beds are found in Worcester, Gloucester and Somerset, as far as the valley of the Parret.

The Triassic of England may be considered under three divisions, which are not the Continental three from which it derives its name.

(*a*) The lowest are soft, yellowish sandstones, which, in some places, contain many pebbles, and are known as the Bunter pebble beds. These beds function as huge water reservoirs, and where they come to the surface as elevations they furnish reliable springs of good water; many Midland towns originated near these. Deep soils are derived from this friable sandstone; they may be poor or good, according as a negligible or a fair amount of clay is mixed up with them. They often occur as valley lands.

(*b*) This is a harder red sandstone which is frequently used as building stone; the strong red colour is due to the films of reddish peroxide of iron, which coat the particles and cement them together. The elevated ground in the Triassic region is chiefly composed of this sandstone.

(*c*) The Keuper marl is clay in which at certain depths lie thin beds of limestone. It is the presence of this limestone which makes the Keuper beds valuable agriculturally. It does not require very deep digging to reach it; it is spread as manure over the fields, thus forming a marl soil. It is in the deepest parts of the marl that the salt deposits of Cheshire and Worcester occur.

The Triassic series of rocks, as a whole, gives rise to a

gently undulating type of scenery, with only occasionally scarp cliffs of the harder sandstones. In Nottingham and the adjacent counties the sandstones are often infertile; they formerly bore much common and forest (e.g. Sherwood Forest). But a good deal of variety appears in the central area, with its large well-timbered estates and varied farming. A great part of the valley of the Trent is Keuper marl.

The western strip, altered variably by admixture with glacial drift, supports well-known agricultural centres, such as Doncaster, Selby and Northallerton.

The Severn, the Dee, the Mersey and the Weaver have cut at least part of their valleys through the soft sandstones (*a*). The Dee has spread many miles of unproductive sand-beds round its entrance to the sea.

The Cheshire plain, being a shallow syncline of Triassic strata, is not uniform in its soils. The river systems cut into the soft sandstones easily; glacial clay gets mixed up with the débris, and there result the soils which produce the well-known Cheshire cereal and fruit crops (e.g. strawberries and plums). The plain is diversified by ridges, such as Alderley Edge, of the hard sandstone (*b*); these are wooded. The marls are pasture land which is used for dairy-farming. The presence of much heavy boulder clay in Cheshire restricts to pasture a good deal of land which otherwise would make good crop land. Barley and oats grow well in this district. Wheat is not a suitable crop owing to the frequency of the rainfall. Extended cultivation of wheat was tried here in wartime. It was not unusual in the autumn to see in the fields wheat in which the ears were sprouting on the stalks as they stood in sodden stooks for many days.

The Lancashire soils, in the district with Ormskirk as

Photo, W. B. Crump

FIG. 8. BEECH HANGER: SOUTH DOWNS

Beech and Yew on chalk. Taken when buds were bursting into leaf.

centre, are well suited for potato culture. The soils are fertile, medium in lightness and well-drained. Ormskirk is a testing station for experimenting on the immunity of potatoes from wart-disease.

The Vale of Eden and most of the flats round the Solway are successfully farmed; they are mixed arable, pasture and woodland. The glacial clays overlying the sandstones are responsible for the formation of Solway Moss, part of which is still useless, undrained bogland.

In Dumfriesshire, the associated Permian and Triassic beds are considered to give soils very valuable for agriculture. Annandale is a typical valley on the southern side of the Scottish uplands, and a typical scene in that valley may be found near the market town of Lockerbie. Silurian beds lie to the south of and under Lockerbie; Permian come to the surface just to the north; as elsewhere in the dale there is abundance of glacial drift. The landscape is a pleasing one; there is a mingling of prosperous farms, well-kept woods, and picturesque streams. No land is left to run to waste; the hills are under cultivation; wide, well-drained holms border the streams. The farms are large. Crops, cattle and sheep all engage the farmer's attention; Lockerbie lamb fairs have long been famous in Scotland, so have Dumfries cattle markets. The crops include oats, barley, turnips, potatoes and hay. It is customary to turn sheep out on the turnip fields in winter, there to eat off the crop. The soil is rich, well-drained and easily worked; rainfall and snowfall are moderate; farming methods are up-to-date.

Nithsdale is better wooded than Annandale, and more romantic. Eskdale is more remote, more elevated, given over more largely to pastoral farming.

CHAPTER X

CHAPTER X

CORRELATION OF VEGETATION WITH GEOLOGICAL STRUCTURE (*cont.*): JURASSIC ROCKS

THE Jurassic System is complicated in its component sub-divisions, but very simple as regards its visible distribution. Minor outcrops being disregarded, it forms a crescentic strip extending from Dorset to Whitby, the Lias being on the inner, western side of the crescent. Our space and our needs will be served by selecting as sub-divisions the following:

OOLITES	*Upper*:	Mainly clay strata, e.g. Oxford Clay, Kimmeridge Clay. Also Corallian Limestones.
	Lower:	Mainly limestones, e.g. Great Oolite, Inferior Oolite and Cornbrash. Also some clay, e.g. Fuller's Earth.
LIAS		Clays, marls, Limestone bands, Ironstones.

The long, irregularly curving line of the outcrop of the Jurassic rocks coincides with a curiously distinct division of England into a thickly populated, manufacturing and mining north-west, and a south-east which is, in the main, agricultural, and has large, thinly peopled, rural areas. Certain of the Jurassic beds face the central plains of Triassic rocks in the form of steep scarps. The Lower Lias

clays come out as a strip lying in front of the scarped faces, adjacent to the Triassic beds; they bear heavy, rich pastures. The highest beds in the escarpment are hard clays, and they fall away to the south-east in gentle dip slopes, towards the face of the next line of elevation, namely, the chalk escarpment. A railway journey from Stafford to London nearly always gives views of flooded fields in the neighbourhood of sluggish rivers; these are parts of the clay plains.

The softer bands of rock form low, level land; the harder rise as escarpments; much of the land is under cultivation. Let us trace the outcrop from the south-west, northwards. In Dorset and Somerset it consists of Liassic marls and interbedded limestones, from which arise good friable soils, suitable for corn and roots, with pasture of calcareous type and woods of ash and oak. The Oolitic limestone forms long escarpments in the south-west; valleys lying west of them have clay floors of Fuller's Earth, etc., and are heavy wet grasslands. The Oolitic limestones break down into light "brashy" soils, used for barley and root crops. The Cotswold Hills are part of the limestone ridges, and are interesting for the exclusive and probably natural beechwoods which share the slopes with wide calcareous pasture land. The rising ground in Warwickshire (e.g. Edge Hill) is marlstone. The highly tenacious Oxford Clay covers wide areas in the central counties, from Oxford north-east to the coast. Its soils are extremely heavy and difficult to drain. The Lias of Rutland and South Lincoln contains much iron and lime, and gives rise to valuable red loams. Kimmeridge Clay (often obscured by glacial drift) underlies much of Fenland and East Lincoln. It is a dark shaly clay, very heavy; in the

Aylesbury district it is lightened by admixture with sand and lime, and is excellent for dairy-farming. The ancient fen-lands (now drained) which lay round the Lower Ouse and its tributaries, covered clays of Recent age resting on Liassic beds. In Lincoln, there are shales with lime, and the farms comprise pasture and plough-land with crops of wheat and beans; where the Cornbrash comes to the surface the soils are light and friable, carrying crops of barley and roots. In the Yorkshire lowlands, drift covers almost all the Jurassic rocks. Totally different from any part of the Jurassic area yet referred to, is the elevated ground the beds form in north-east Yorkshire, where they constitute the great mass of the North York Moors. Jurassic beds are marine everywhere else in England, but estuarine in north Yorkshire. Numerous beds of sandstone and shale, with limestone in the southern part, are built up into the plateau with its steep escarpments overlooking Teesdale and the Vales of York and Pickering. The northern moors bear natural vegetation; the southern Corallian limestones make good farm-land, under dry sunny conditions, yielding good crops of corn.

The North York "moors" form an area in which the native rock, in the main, determines the vegetation. The following facts have to be kept in mind: (*a*) Except marginally, the country is free from the complicating factor of glacial deposits. (*b*) The surface is level or gently sloping, but intersected by deep drainage valleys and peculiar glacial overflow valleys. (*c*) The rainfall is not heavy (*c.* 35 inches), but the humidity, partly owing to sea-mists, is higher than farther south along the coast. (*d*) The surface rock of the high moorland is everywhere

sandstone, grit or sandy shale of Inferior Oolitic age, very coarse in its weathering, with many blocks of stone strewn around. Only on the Hambleton and Tabular hills in the south do there occur strata which, in large part, are calcareous of the Middle Oolites. The valleys cut down into Liassic rocks. (*e*) This is a tract of country in the river valleys of which great lakes were held up in glacial times, and the outflow channels, cut across the drainage slope by torrents emptying these lakes at a certain stage in their history, have persisted in the present topography as short "dry" valleys, whose vegetation has its own special features. (*f*) Glaciers impinging on the coast mounted the cliffs, and glaciers coming down Teesdale pushed up the northern valleys and over the moor-edge, choking and often permanently changing the courses of rivers and leaving a fringe of clay round the tableland.

The vegetation follows the three geological belts most exactly. The exposed sandstones display one of the most magnificent heather moorlands in the country. Commonly they are termed "moors": in strict botanical sense they are "heaths" (p. 58). A ground section shows below the heather: thin peat (*not* the thick peat of a moor), sand with humus, and often below this a thin layer of *pan* (p. 39). The plant which holds the ground is *Calluna vulgaris*; where this is aged and straggling, mosses (*Hypnum*, etc.) and lichens (*Cladonia*) thrive beneath its branches; locally, bilberry, crowberry, cowberry are associates; on the sandy slopes *Calluna* and bracken (*Pteris aquilina*) strive for mastery, the defeat of the latter invariably certain at the top of the slope.

The calcareous outcrops are all cultivated and form

mixed farms of corn crops and grassland—even up to twelve hundred feet.

The marginal glacial drifts of the east, north and west, give rise to soils which are well worth developing, and farming is carried on there also. Left untouched, the drift is covered with grass, scrub or heath.

The valleys cut through strata differing lithologically, and their respective zones of vegetation can be easily traced from distant view-points, e.g. *Calluna* heath on lower slopes of sandstone, grass or bracken on middle calcareous belts, *Calluna* again on upper sandstone. The slopes of many of the valleys either are, or have been, covered with woodland and scrub (often a retrogressive phase of woodland). W. G. Smith states that oak-ash woods prevail in the lower ends of such valleys as are cut down into the calcareous Oolites, and are replaced by oak-birch in the siliceous valley heads.

The "slacks" or "swangs" are the deep, often short, now badly drained, valleys of the glacial overflows; their bottoms are of deep peat—*Sphagnum* bogs, *Eriophorum* bogs, *Juncus* bogs; the better drained are grass-covered. The sides of these "dry valleys" or "overflow-channels" are grassy, heather-clad, or hidden in bracken. The North York Moors form one of these districts which, in glacial times, had the drainage held up in lakes in the side valleys. Torrents from these lakes cut through the watersheds; the "dry valleys" are the forsaken beds of these torrents. A very large lake occupied what is now the Vale of Pickering; it will be referred to when studying recent deposits (p. 139).

Until the construction of the cross-country railway from Whitby, the north-east Yorkshire Dales were very

isolated. Canon Atkinson's *Forty Years in a Moorland Parish* describes the life in Danby Dale near Castleton in Eskdale. From Castleton one looks up to a moor edge, rising almost precipitously in front of the village. One may watch a horse and cart outlined against the sky, travelling along the very line of road probably used by the ancient Briton. The Briton found the moors to be dry by comparison with the swamps of the valleys, and he kept to them in his journeying and for making his dwellings. If you climb up to the moor face you find that he placed his burial mounds all along that moor edge, as the Roman noble placed his stately, family tombs alongside the Appian Way. He, we may suppose, had as glorious a prospect as we have—the splendid heather purpling the ground for miles. We see, cutting across part of it an ugly wound made by man where he has quarried for road-metal the whinstone "dyke," which is an intrusive igneous rock of great hardness. We see the rubbish heaps which tell that he has been seeking coal, or iron, or building stone. If we go farther into the heart of the moor, we may come suddenly on a steep-sided gully —a dry valley—perhaps one which has reached a stage of wood or shrubland, perhaps with only fern, heather, and grass. If we start from farther east we may reach the wet, gloomy, semi-cauldron of Moss Swang, whose very name is suggestive of dreariness. The moors are places of wide spaciousness, fragrant with the multitude of heather blooms, swept with the keen winds from the North Sea, overarched by fair skies.

The heavy loams and clays of the Kimmeridge and Oxford beds of England ought also to be distinguishable by natural vegetation. These beds, however, are exposed

in the less elevated districts, and their natural vegetation was destroyed at an early date when man made them into enclosed land. The traces of what are left can be illustrated better elsewhere (p. 131). The natural woodland which was once universal is the association of the pedunculate oak (*Quercus Robur* L., *Q. pedunculata* Ehr.). The existing woods are maintained as standard and coppice woods; the oaks are spaced well apart, and the interspaces filled with hazel, small oak, ash, birch, which are cut back regularly to foster the growth of coppice shoots. In such woods as these the partial shade favours luxuriant growth of bluebell, primrose and wood anemone. On very wet ground an *Alder-willow Association* is common. The grassland is styled "neutral," because its members do not include those peculiar either to calcareous or to siliceous soils. The turf is very compact, and many other herbaceous plants are associated with the grasses.

The Jurassic clays underlie part of Fenland, which will be described in connection with recent deposits.

CHAPTER XI

CHAPTER XI

CORRELATION OF VEGETATION WITH GEOLOGICAL STRUCTURE (*cont.*): CRETACEOUS ROCKS

THE Cretaceous System derives its name from the chalk which forms its uppermost and most massive and extensive member. The principal beds included in it are:

UPPER CRETACEOUS	Chalk Upper Greensand Gault
LOWER CRETACEOUS	Lower Greensand Wealden Clay Hastings Sands

The beds of sand and clay which lie below the chalk were deposited in shallow seas, some of them in estuaries. The waters deepened as what we now call the Cretaceous Sea crept up from the south-east. In its greatest extent, we know that this mighty ocean rolled where now is eastern Ireland, across the breadth of southern Europe and northern Africa, and far into Asia; how far beyond this we know not. In the bed of this sea the chalk was deposited. It is a very pure limestone, with as much as ninety-eight per cent of calcium carbonate in its upper beds. Zones crowded with flint nodules occur in it, and some small areas are rich in phosphates. The soils which lie above it are not always calcareous, for the lime may be carried away from them entirely by percolating water. Residual beds cover certain tracts. They are sandy or

clayey, and are supposed to be what is left after the calcium carbonate of an impure chalk has been removed, or to be the residue of beds higher than the chalk. The soils derived from these layers require manuring with lime if they are to be of agricultural value. The soil covering of the North Downs is generally a clay, with numerous flints scattered through it.

The beds lower than the chalk are confined in their surface distribution to south-east England. The chalk gives rise to very distinctive features of English scenery. It is elevated as a second very long line of scarped land, running parallel with the Jurassic escarpment; its scarp faces look down on the dip slopes of the Jurassic clays, whilst it also dips to the south-east; the line is broken up into hill-groups by river-gaps. This sweeping line begins with the hills of Dorset and Devon; widens into the plateau of Salisbury Plain; then strikes approximately north-east as the Marlborough Downs, the Chilterns, the Norfolk Hills, the Lincoln Wolds and the Yorkshire Wolds—ending at Flamborough Head.

What is called the Wealden uplift has a very obvious geological history. At a time subsequent to the deposition of the Cretaceous beds the earth's crust in an area which included south-eastern England, was pushed up into folds having an east to west axis. The Weald region was one of these anticlines. Part of the northern limb of a second is seen in the highly tilted chalk-beds of the Isle of Wight. The second phase in the history of the Weald was its denudation—marine and aerial. Long oval slices were removed from the top of the dome-like fold, thus exposing the beds of which it was composed, in a double succession from the two sides towards the central long axis. These

beds were unequally resistant and the next stage of denudation left upstanding a central line of heights with a depression to the north of them and one to the south, these in turn being bounded on their outer sides by strips of sandstone and a higher rim of chalk. The chalk ridges are the North and South Downs of to-day; they join together in the west and run on into Hants and merge into Salisbury Plain. The rim of Wealden limestone is broken on the east, the North Downs ending in South Foreland, and the South in Beachy Head. Between them the Wealden Clay beds touch the coast.

It is highly probable that the chalk was laid down over the whole lowland area of the British Isles. There is evidence to support this in the occurrence of such widely separated outcrops as those underlying the plateau of Antrim and those in the north-west of Scotland.

A chalk landscape is unmistakable in its contours, whether in Kent or in Yorkshire. Its lines are wonderfully fine. The curves of its undulating hills are strong, free, and yet gentle. The summits are smoothly curved or flattened. Where the heights break off at the sea, their cliffs are magnificent—sheer and lofty. There have been frequent changes in their drainage systems; river-courses have been abandoned and appear as dry valleys; sometimes these end on a sea-cliff, the valley end being high above the beach, often spoken of as "hanging valleys."

The free, open surface of the chalk hills is uniformly carpeted with close turf of short, sweet grass, often entirely free from trees or shrubs. The valleys may, if the water-supply is good enough, be wooded and cultivated. To wander from hill to level, and from level to secluded valley, amongst the undulations of the Yorkshire

Wolds, impresses one with a weird stillness — without trickle of water, without rustle of tree, with rarely the cry of a bird.

We pass now to the consideration of the vegetation characteristic of the Cretaceous area, non-calcareous in type and calcareous in type.

For the first time we now meet with extensive examples (more limited have been seen already on the Bunter beds) of the *Plant Formation of the Coarse-grained Sandstones* —those of the Secondary and Tertiary Periods as distinct from the fine-grained Primary sandstones. The newer sandstones break down more quickly and form lighter and more porous soils from which mineral salts are readily carried away by leaching: they hold little lime and are often deficient in humus. They bear woodland and heath. The woodland is the *Dry Sandy Oakwood Association.* Mingled together in it are both the pedunculate oak and the sessile oak, whilst beech frequently forms societies within it. Pine and birch may be present; sloe and hawthorn as shrubs. When birch assumes more prominence an *Oak-birch Heath Association* arises. This wood is varied by wide patches of bracken, heather and grass, and Scots pine may make its way into it. It constitutes the forests in the centre and round the margins of the Weald, on the sandstone strata—forests which are still of great extent, though a mere fragment of what they were formerly. It may be a type of wood which represents a stage on the degenerative way which ends in the *Heath Association.*

The Chalk vegetation constitutes a *Sub-Formation of the Calcareous Rocks* (see p. 86). It presents as distinct Associations, Beechwood, Ashwood, Chalk-grassland.

FIG. 9. HEATH VEGETATION OF BRECKLAND

Orientated photograph on long transect across the transition zone between *Calluna*-heath and grass-heath where the *Calluna*-heath is degenerating to grass-heath owing to rabbit attack. Note rounded shape of the rabbit-grazed *Calluna* bushes.

By courtesy of Dr. W. Munn Rankin

FIG. 10. HAZEL COPPICE ON LONDON CLAY

Principal members of ground carpet are dog's mercury and primrose.

The Beechwoods are striking features of the valleys of the North and South Downs and the Chiltern Hills, and to a less degree other chalk hills. They cover the gentle slopes from the summits nearly to the valley bottoms, and obtain a foothold on the escarpments. It is only on the chalk and (probably) on the Oolitic Cotswolds that native beechwoods, as distinct from plantations, have a proved existence in Britain. Beech forest, in Denmark, occupies humus-soil. Beech forest, stated to be ecologically equivalent to English beech forest, occurs on schists in the Cevennes. This suggests that factors other than the nature of the rock enter into the question of the distribution of the beech.

An Ashwood Association replaces beech on the chalk west of the Downs.

A curious association is that of the *Yew Woods* (*Taxus baccata*) of Sussex and Hampshire. They may be compared with the much more restricted clumps of yews which maintain a footing on the face of the limestone scars in Yorkshire.

Within the *Scrub Association* of the chalk collect many plants from surrounding soils—hawthorn, sloe, juniper, holly, roses, etc.

Chalk Grassland has as dominant *Festuca ovina.* It prevails almost generally over the chalk and in a notably pure community on the South Downs. Where it lies on the summits of the hills it is almost certainly very ancient pasture. Its turf is compact, crowded with many species besides grass, and is closely cropped. Some of the plants are calcicoles, having roots which pass into the deeper calcareous layers, e.g. salad-burnet and rock-rose; others

with short roots are indifferent to lime, and are content with the poorer surface soil.

The *Hastings Sands* form the central member of the strips of the denuded Kentish area, touching the sea in the east. They rise in elevations such as Ashdown Forest.

The *Wealden Clay* encircles the Hastings outcrop. It is a low-lying wet land of stiff heavy clay, poor in lime. As its name shows, it was once covered with forest. It is still partly wooded, bearing the damp oakwood type belonging to clays and loams. Mainly, it is under permanent pasture.

Round the Wealden Clay runs the escarpment belt of the *Lower Greensand*. As hilly or level patches it is scattered all over the Cretaceous area. It generally gives rise to light soils containing little lime, on which grow poor grass and woodland. Where the soil is improved by rainwash or alluvium it carries good crops.

The *Gault* is the next parallel band in the Weald anticline. It is a stiff bluish clay, deficient in lime; it underlies a strip of generally wet grassland. The eastern Fens rest on Gault.

The *Upper Greensand* exists only as small exposures in Kent; there is more of it in Hants. It produces good soils when mixed with lime from the adjacent chalk. The steeper slopes are wooded, the woods being described as "hangers."

Nearly all the more level exposures are under intensive cultivation, especially for hop-gardens. Chalk added to Upper Greensand forms good wheat-land.

The *Chalk* soils are extensively cultivated, especially those of the Middle and Lower Chalk. The grassy uplands

are famous as sheep-runs; the open, free situation, the dry surfaces, and the nature of the grass, all favour the high quality of flesh and wool which belongs to the sheep of the Downs. Farming of mixed type is carried on on the lower slopes and in the valleys. Some of the most highly farmed districts are: the northern slopes of the North Downs, parts of Salisbury Plain, and the Yorkshire Wolds. The soil on the Wolds is thin and the grass is not very dependable. Farming is not easy. Sheep can be maintained throughout the year only by feeding them for part of the time on clover and turnips, both of which they eat on the ground. These two crops unfortunately are not always safe to be plentiful. Oats and barley are the chief crops, and for their success the ground must be heavily manured.

Kent presents striking contrasts in the surface values of its land—its dry, grassy sheep-runs on the chalk, its wet grasslands on the clays, its woods on various soils, its waste land on poor sands, its remarkable fruit, vegetable, and flower growing on the mixed soils. The predominance of the fruit industry can be traced to several favourable factors.

(*a*) There are very fine soils, good mixtures of sands and clays with lime.

(*b*) There is a rainfall sufficient to ensure spring growth and also the swelling of the fruits, without its being so heavy or so frequent as to hinder ripening.

(*c*) Kent is one of the sunniest parts of England, therefore early maturity of fruit is encouraged, whilst the spring blossoms and buds are not so liable to be ruined by cold east winds, as is the case farther north along the east coast.

More hops are grown in Kent than anywhere else in England; the industry is very highly organised and very profitable. Kent strawberries and Kent cherries are the earliest English crops of these fruits to be put on the market. Apples, pears, and plums are also widely cultivated. So, too, are wheat and barley.

CHAPTER XII

CHAPTER XII

CORRELATION OF VEGETATION WITH GEOLOGICAL STRUCTURE (*cont.*): TERTIARY ROCKS: EOCENE TO PLIOCENE

THE Era of the deep chalk sea which for so long rolled where is now south-east England, passed away. It was succeeded by what the geologist calls the Tertiary Era, within which this area experienced many ups and downs, but which was, in the main, an estuarine or a shallow-marine period. Tertiary times, in their world-wide significance, are of unique interest, because within them so many of the physical features of the world—mountain, plain and valley—were given the outlines they now bear.

Sedimentary rocks of Tertiary age are found in the British Isles only with slight exceptions in the south-east; it is these which form the subject of this chapter. At intervals throughout this age, which, of course, was a long one, volcanic activity of an intense character made violent play with the land surfaces which stood up in the north-west. It has left for us the basalts, etc., of the west of Scotland and the north of Ireland. These have already been described (see p. 64).

The succession of Tertiary beds has been divided and named in accordance with the principle of the degree

of resemblance which exists between their fossil remains and forms now living. The divisions are:

(4) Pliocene.
(3) Miocene.
(2) Oligocene.
(1) Eocene.

They are surface beds within two well-defined areas:

(*a*) The Hampshire Basin, which is a shallow trough, embracing a large part of that county.

(*b*) The London Basin, triangular in area, having the apex of the triangle in the neighbourhood of Newbury, one long side extending from there eastwards, and embracing a strip between the Thames estuary and the North Downs, and the other long irregular side terminating on the coast of North Norfolk. Excluding Norfolk, Suffolk, and North Essex, the immediate valley of the Thames may be regarded as a distinct unit. Both this unit and the Hampshire Basin have a surface uncomplicated by glacial deposits. The East Anglian area is heavily shrouded in drift of various kinds and coated in addition with more recent accumulations of alluvium, etc.

(i.) **Eocene.** There are identified within this period the following sub-divisions, beginning with the lowest: the Thanet Beds, the Woolwich and Reading Beds, the Oldhaven Beds, the London Clay, the Bagshot Sands and the Bracklesham and Barton Clays.

The Thanet Sand is marine, and of comparatively small extent.

The Woolwich and Reading Beds are marine sand in East Kent; in West Kent, East Surrey and part of Essex they are the sandy and clayey sediments of an estuary;

in Hampshire and the marginal part of the Thames basin they are fresh-water sediments. The woodland associated with these beds is typically dry oak-birch, in which the dominant tree is *Quercus Robur*. Within the wood the chief members of the undergrowth are brambles, bracken, foxglove, wood-sage, etc. Where the sands are very coarse and open, mixed with gravel, or where gravel itself predominates, *Calluna* heath covers the ground. In places, plantations of pine and birch have been established and the best of the land supports mixed farming.

The Oldhaven Beds are of sand and flint pebbles; they are of local occurrence.

The most important member of the Eocene series is the London Clay. It was spread out along the margin of a sea which covered both the London and the Hampshire Basins. It contains remains of land animals and plants. It underlies London and is a surface rock for a considerable distance beyond it. The physical features and vegetation of the country in the neighbourhood of London are determined very assuredly by the London Clay on the one hand, and by the Bagshot Sands on the other.

The typical wood of the heavier clay soils, which has as its dominant the pedunculate oak (*Quercus Robur*), flourishes on the London Clay. Included amongst its shrub plants are hazel, hawthorn, sloe. The bramble and the brier make tangled growth within it; the foxglove thrusts its spikes of rich bloom through the tangle; honeysuckle and ivy find spots which suit them. Varying with the closeness of the trees to one another, there is a varied and abundant ground vegetation, including wood anemone,

violets, lesser celandine, enchanter's nightshade, scabious, ground ivy, ferns, etc. The cultivated land is devoted largely to dairy farms.

The next geological phase saw the shallowing of the sea and the materials of the Bagshot Sands and the Bracklesham and Barton Clays being carried out into it by a river coming probably from the west.

The Bagshot Sands give rise very often to hilly country. They are exposed near Aldershot, and they build up Hampstead Heath, Bagshot Heath, Blackheath. They bear woodland, heath, or grassland which merges by gradation into heathland. There is a good deal of variety in the woods, associated generally with the varying proportion of clay which may be mixed with the sand. The driest woods are essentially of the sessile oak (*Q. sessiliflora*). *Quercus Robur* comes in in increasing numbers with clay; hornbeam is an associate. Plantations of Scots pine are of frequent occurrence. The birch groves of Epping Forest stand on the sands. Scrub associations, which may be stages in the degeneration of woodland, are characterised by the presence of hawthorn, birch, gorse, sloe.

A good deal of varied heath is borne by the sands and the plateau gravels to the south-west of London. *Calluna* is the dominant. A striking feature is the spread throughout the heath of *Pinus sylvestris*, the seeds of which have travelled from the plantations near by.

There are wide stretches of grass-heath. Its chief grasses are *Agrostis vulgaris* and *Holcus mollis* (also in the woods), and scattered over it are clumps of gorse and bracken.

The tertiary sands and gravels of Hampshire are clad

either in heath or with fine woods, or are farmed as arable land. The heath is chiefly *Calluna*, which is accompanied by its usual associates. The woods are oak of the dry, sandy type. As intermediate associations there occur oak-birch heath and grass-heath. *Pinus sylvestris* sows itself abroad here as it does in the London area. For cultivated land the agriculturist takes advantage of the localities where the limestone peculiar to the Hampshire Tertiaries is added to a soil of sand and clay. The strawberry culture of the county is famous.

(ii.) **Oligocene.** These beds are exposed only in the Isle of Wight and at Bovey Tracey in Devonshire. They are estuarine or freshwater. They are too limited in area to call for special mention.

(iii.) **Miocene.** Of these we have no representatives in Britain.

(iv.) **Pliocene.** These deposits are found in Norfolk and Suffolk. They are the sands, gravels and marls, with their abundant admixture of shelly débris, which are termed "Crag." They form very flat country. Their character is often obscured by vast amounts of glacial drift spread over them as well as by the alluvial deposits in the Broads and elsewhere. The mixture of sands, gravels and clays, together with glacial lime, furnishes a soil, which in point of food-content and drainage is ideal for wheat. Where the sand predominates decidedly, heath conditions for vegetation are set up. These will be discussed more fully on pp. 140–42.

By far the heaviest wheat production in England is located in the coastal counties between the Thames and the Wash. The soil is strong enough, the winter and spring rains are adequate, and hot, unclouded summer days

can be depended on more safely here than elsewhere in the British Isles. In addition to wheat, there are grown heavy crops of barley, potatoes and turnips. The nearness to such a market as London encourages extensive market gardening; there are fields of peas and beans, large orchards, etc.

CHAPTER XIII

CHAPTER XIII

CORRELATION OF VEGETATION WITH GEOLOGICAL STRUCTURE (*cont.*): PLEISTOCENE ROCKS

WE speak of the Pleistocene as the Glacial Period of the Northern Hemisphere. It was intensely cold; northern and much of central Europe was sheeted in thick ice; the Swiss glaciers moved far outside their present bounds. Nearly all the British Isles lay under this icy covering, which slipped and flowed in all directions. Its southern edge seems to have stopped a little north of the Thames Valley; all Ireland was under it; its western front of ice-cliffs dipped into the sea from south-west Ireland to Scandinavia. The North Sea was full of ice; so was the Irish Sea. Some heights seem to have been free from it, e.g. the North York Moors, peaks in the Grampians, etc. The present watersheds seem to have been, even then, the chief areas of precipitation, and the sheet-ice on their sides and the glacier-ice in their valleys streamed away in the directions that would now be taken by water. Many of the Pennine dales had glaciers, and some of their ice reached the Midlands and even East Anglia.

The influence of the Ice Age on British vegetation—natural and artificial—has been incalculable, which is the reason for its being introduced into these pages. It is necessary to know what re-distribution of the surface rocks was accomplished by the ice. As is usual, the glaciers bore on them and within them a burden of

broken-down rock, ranging in size from dust to boulders weighing tons. They ploughed up the soft rocks they met in their beds, scratched and polished the hard, ground fragments into finest powder, sent powder and sand and pebbles forth on long journeys in their melt-waters or laid them up in ridges in their moraines. Glaciers in main valleys dammed up waters in side valleys, which lakes have left their shore-lines and their beds of silt behind them. Everywhere in our Islands we meet with this travelled—sometimes far-travelled débris. By far the most striking and important in relation to vegetation are the *Till* or *Boulder Clay* deposits. Taken in its widest meaning, the term includes clays, sands and gravels, and is known as glacial *drift*. This drift often entirely masks, or even reverses, the influence of the native rocks on the plant life of a district, and would do so more frequently, but that the great mass of the drift is likely to be of local origin. No generalisation can safely be made as to its constitution or the soils arising from it; a few typical areas will be indicated.

Already the high-lying sheets of boulder clay left on the plateaus of the north-west Highlands have been mentioned as holding up the drainage of wet moorlands. W. G. Smith states that the soils of the Scottish lowlands up to one thousand feet are mainly either glacial or alluvial in origin. He traces a grass-moor association of grasses, rushes and sedges, intermediate in character between siliceous grassland and *Scirpus* moor, as being characteristic of the boulder clay deposits on the flanks of the Scottish Hills. It is an association of great extent—in the Highlands, on the Ochils, the Pentlands and the Southern Uplands.

Photo, R. M. Adam

FIG. 11. SCOTTISH FARMLAND, NEAR TAYPORT, FIFE

Wheat-field in stook; turnip crop beyond; typical tree-clad undulating land in distance.

The soils in the central trough plain of Scotland are a rich mixture of the materials which came down from the granitic and metamorphic rocks of the Grampians, of the volcanic rocks of the Ochils, Fifeshire and the Lammermuirs, and of the Old Red Sandstone of the western outcrops. They partly account for the fine corn and dairy farms of Ayrshire, the noted crops of Strathmore, the Lothians and Tweedside. Aberdeenshire depends for its farm land on soils of drift. The Galloway farms get their well-mixed soils from the Galloway hills to the north.

A very large area in England, including part of Yorkshire, the central counties, Cambridge, Bedford and the border of East Anglia, is covered with the "Great Chalky Boulder Clay." This deposit varies from place to place, but always contains lime; it is derived mainly from the Jurassic and Cretaceous beds on which it rests, but it may also have embedded in it numerous far-travelled boulders, e.g. from the Lake District, the Cheviots, the Pennines and Scandinavia. Its soils may be heavy wet pasture soils as in North Yorkshire, rather heavy clays, like the wheatland of Holderness, or loamy marls, like those of the fertile Vale of York.

The traveller from York to Scarborough by the North-Eastern railway crosses a fine example of country the configuration of which owes much to glacial action. Just beyond Castle Howard the train enters a narrow cleft in the hills; shortly before Malton is reached, it emerges in full view of the perfectly level expanse of the wide Vale of Pickering, free from hedges or walls, lakelike in its uniformity of surface. This area actually was occupied by a lake in glacial times and its soil is derived from the mixture of mud, sand and coarser material brought down

into it by ice-water from the surrounding heights. The potential fertility of the soil of this alluvial land is much lowered by the tendency for water to lodge, owing to the very slight fall in level over many miles. It is farmed with diligence. Open drains cross it in all directions, and success has been so far attained that the areas of wet peat are not large. They are planted with Scots pine and form the "Carr" woods. The crops grown are rye, barley, oats and turnips. On the heavier land the old Saxon plan of a "fallow" year in the rotation is sometimes substituted for the year of root crops. Sheep are not numerous.

In Lancashire and Cheshire the local contributions to the drift are from the Triassic sandstones and marls, the boulders being often of Scottish and Lake District origin. There are two types of soil—the heavier with dairy farms, and the lighter, more sandy, with crops.

The drift of the Midlands is very variable in character.

Chalky boulder clay covers part of the chalk in West Norfolk and Suffolk. Over the clay, over the chalk, and also over the Tertiaries of these counties are spread sands and gravels which may be wholly or partly glacial. This very porous soil, occurring in a climate of low rainfall (25 inches or less) has promoted a type of vegetation more like that of steppe than is seen anywhere else in England. It extends eastwards over the "Crag" strata of the coast. It is the *Heath Formation* of East Anglia. A portion of it, the *Breckland* from about Cavenham to Brandon, has been studied very exhaustively by E. P. Farrow, and the results have been published in the *Journal of Ecology*. The heath has no natural woods, and probably never had any. Its vegetation is sparse. *Calluna vulgaris* association alternates apparently fitfully with a

grass-heath association of *Festuca ovina* and *Agrostis vulgaris*. There are minor communities of *Carex* and *Pteris*, and small plantations of *Pinus*. In the spaces of the discontinuous grass-heath, there is an unusual number of annuals, a point to be compared with their prevalence in steppe and desert. Professor Marr considers these heaths, which are really an extension of those of the North German plain, to be relics of an ancient westerly extension of Russian steppe.

Some of Mr. Farrow's most interesting conclusions may be stated here; the whole memoir should be read as being the record of recent ecological research on original and carefully applied methods.

(*a*) He attributes the relative distribution of the various associations to the rabbits which swarm on the heath. As food they prefer heather to grass, grass to sedges, and sedges to bracken. This preferential treatment he brings proof to show is the reason for the prevalence in certain spots of the grass-heath (another theory is that such spots have higher lime-content); the rabbits destroy the *Calluna* and the grasses move in; it is shown how, when the *Calluna* clumps have been mutilated by the rabbits, the lichen *Cladonia* and the moss *Leucobryum* set up a most luxuriant growth in the middle of the bushes, and smother the heather to death.

(*b*) The rabbits keep the grass-heath nibbled down very closely; in particular, they are extremely destructive to inflorescences, which in the end means the extermination of species.

(*c*) Rabbits kill off the seedling pines, which make attempts to extend the valley woods over the edge of the heath.

(*d*) The pioneer bracken plant of a *Pteris* community springs up at the entrance to a rabbit burrow, within the shelter of which the wind-borne spores can develop into the delicate fern prothalli.

(*e*) Bracken is advancing both amongst grass and heather. It kills its competitors by smothering them with its dead fronds, and has for allies the rabbits, killing by other methods.

(*f*) The scarcity of water is the limiting factor in the rate and extent of growth.

(*g*) The capacity for growing tall rapidly is of great importance in competition among plants, as is shown when water is sufficient to enable *Agrostis* to overtop *Festuca*.

(*h*) It was found out that the spreading of *Carex* past a narrow belt of pines was due to the inability of the upright shoots arising from the rhizomes to penetrate a great thickness of pine needles and cones, the rhizomes of *Carex* running at low levels.

(*i*) The numerous bare areas, and the areas dotted over with dome-like clumps of grass and heather, are degeneration areas—broken up by "sand-blasts," that is, by fine streams of sand carried along by the wind.

Several of the principles illustrated above are of valuable application to wider problems of plant distribution.

Passing to the Pleistocene deposits of Ireland, we find that much of the central plain, as well as the lower inner slopes of the encircling hills, is covered with drift. It contains much lime. It is often the rock-bottom of the bogs, but where drainage is practised it may break down into good marly loams of agricultural value.

By courtesy of Dr. W. G. Smith

FIG. 12. FARMING ON ALLUVIAL LAND: MOORFOOT HILLS

The hill on the left is wooded up to 1500 feet; *Calluna* with burnt patches lies above that. In the foreground is mixed grass-*Calluna*-heath. The enclosed land consists of hay-meadows.

Post-Glacial Deposits

Alluvium. This is a most important member, from the agriculturist's point of view, of the Recent series of deposits. The term is applied to the partially consolidated sediments which rivers spread over their valley bottoms, over the beds of lakes or as deltas at their entrances to seas. It also covers the accumulations of silt and sand which tidal waters may carry inland and leave behind. Under proper treatment these sediments become most valuable farmland. When of suitable chemical character, properly drained, and conveniently situated for markets, they are made the foundation for intensive market-gardening. The alluvial strips bordering some rivers constitute "holms," or meadow pastures. They may form first-class arable land. As the alluvium consists of material which has probably been derived from several kinds of rock, its ingredients are likely to contain variety of plant food. Probably also, particles of various sizes will be well mixed together, thus favouring easy tillage and free root-growth. The occasional flooding of valley land may spread thin layers of fresh soil over land reduced by cropping—a species of natural fertiliser. As extensive examples of alluvial deposits may be mentioned those parts of Yorkshire which are crossed by the lower courses of the rivers which unite to form the Yorkshire Ouse. These rivers have brought down from the Pennines plenty of lime in solution and in suspension. The alluvium they deposit in the plain contains the elements of fertility, provided it does not become water-logged. This in early historical times it was, spreading out as many miles of marsh. Now, the

merest fragment of the bog-land is left; the reclaimed land is fair as farms can make it.

The Clyde is another river which has built up great areas of alluvial land in the middle and lower parts of its course in Lanarkshire.

As continuations extending inland, sometimes for miles beyond the existing heads of estuaries on the Scottish coasts, there run flat terraces of alluvial character. In comparatively recent geological times they were estuarial sea-beds. Their emergence is due to alteration in the relative levels of land and water; it has added good land to the coast; they are known as "raised beaches"; two levels are well represented, the twenty-five-foot beach and the fifty-foot beach. They stretch round the Firths of Clyde, Forth and Tay, as well as elsewhere. The soils consist of laminated clays and sands, associated with gravel. Historical records speak of them as covered with morasses; now they constitute the well-drained "Carses" of Scotland, famous for their fertility.

Marshland. Not all river-valleys are by nature good farm-land; man must drain, and has drained, and must continue to drain some of them. Otherwise, they may lie permanently water-soaked or even water-covered. Marsh-land bears a distinct plant community, the *Marsh Formation*. Woodland is possible as part of it, along stream-banks and around semi-permanent pools. The woods belong to the *Alder-Willow Association*. It must be noted that under the marsh formation there is no substratum of peat.

There is evidence that the marsh formation may change into a *Fen Formation*. The essential difference between them is that peat is present in the latter. The

peat may be deep. It is always alkaline in re-action, which distinguishes it from the peat of moor and heath. The most extensive and pure fens of England are those at the mouths of the Norfolk rivers which enter the sea near Yarmouth. There we find a maze of river-channels, shallow lakes called Broads, and strips of intervening fenland—and every sign that fen is being built up from marsh, and marsh rescued from water. The soft water-soaked soil maintains two associations—the *Fen Association* of grasses and sedges, and the *Carr Association* into which the drying fen may develop; the carr is woodland with alder, willow and birch as dominants.

The extensive lowland surrounding the Wash—the Fens—is on its seaward side marine silt; farther inland it is fen-peat; and farther still river and glacier deposits. The greater part is now well-drained and productive land.

What is known as the *Fenland* is, by its history, a structural continuation of the Wash. At the time when the chalk escarpment ran unbroken, except for river gaps, from Hunstanton to the Wolds of Lincoln, a plain of soft clay surface lay to the west of it. The sea wore down the chalk barrier and took possession of this plain, and a bay much greater than the present Wash would then curve inland. Next, the bay began to fill up with sediments; the sea gradually undid its own doings, massing at the head of its bay the spoils of which it had robbed the coasts of Lincoln and York. It is still doing it. Mile after mile has been converted into land, and still the Wash grows shallower and more restricted. The land so given back is perfectly flat, and, therefore, certain to suffer from flooding by the rivers which crawl across it. Until man applied his science to the draining of it, it was

a succession of swamps—almost a lake in winter. Where the harder Jurassic rocks stood out from the flat there were so-called "islands," such as Ely and Thorney. It was on these that towns were established. The drainage schemes have been most successful. Great, well-protected cuts carry off the surplus river-waters; storm-dykes shut out the sea-waters. The alluvial portions of the region are fertile and easily worked. They are under varied crops of market-garden character, as well as the heavier crops of wheat and beans. The estuary of the Humber is well known as a region of naturally shifting tidal sands and heavy river deposits. By a system of "warping" a great deal of valuable land has been created. Silt-laden sea-water is conducted by wide drains provided with sluices over low land, which is divided into compartments; the water is retained until the fine earth in it settles, and is then released; silt one to three feet deep is allowed to gather. It is dried and cultivated.

The very extensive marshland which covered much of East Somerset, e.g. Sedgemoor, has been greatly reduced by draining.

Another stage in the evolution of vegetation on alluvial soil which may be reached, is that of the *Lowland Moor*, in which the alkaline condition of the fen has given place to an acid condition with corresponding changes in the plant life. W. M. Rankin describes a most interesting instance of this which occurs near Morecambe Bay. Its vegetation is now an *Eriophorum-Scirpus* moor, with a curious admixture of *Sphagnum*. The peat beneath gives an epitome of its history:

(*a*) The lowest layers are marsh and fen remains resting on estuarine silt.

(*b*) Peat with birch and pines (moor).

(*c*) Peat with *Sphagnum* (very wet moor).

(*d*) Present phase of peat which is of a drier type than (*c*), and is becoming still drier, so much so that *Calluna* has spread over parts of the moor.

Sand-Dunes. Masses of sea-driven and wind-driven sand are piled up along parts of our British coasts, notably in the Cornish Peninsula, in Cheshire and Lancashire, in East Anglia, along the Moray Firth, in Aberdeen and in Fife. This sand, flung up by the sea, is distributed by wind, and, if unhindered by natural or assisted vegetation, may be spread over the neighbouring inland areas to their great harm. It is a matter, therefore, of importance that the mobile or shifting dune should be "fixed." Colonies of plants can accomplish this, such plants as possess a root-system copious enough to get sufficient water from their loosely-compacted habitat, and to withstand the onslaught of strong winds; they must also be able to endure burial by drifting sand and to force a way through to the surface again. The commonest and the most competent colonist which we have on the British dunes is the marram grass (*Ammophila arenaria*). It is the dominant in the *Marram Grass Association*, of the *Sand Dune Formation*. In some districts, e.g. near Southport, another association, that of the sea couch-grass (*Agropyrum juncei*) binds together those dunes nearest the sea. Here too, in the hollows amongst the dunes, there occurs an association of the creeping willow (*Salix repens*). As the dunes grow firmer plants from the landward side move outwards over them, and *fixed-dune* associations of mixed character spring up. Nearly all the plants of the sand-dunes display some kind of xerophytic modification.

The grasses have tough, furrowed and rolled leaves; sea-holly has wax-coated leaves; sedum and the sea-purslane (*Arenaria peploides*) have succulent leaves; *Salix repens* has woolly hairs, and so on; whilst it is a significant link with the steppe and the desert that many species are annuals. Profusely branched roots and great rhizomic development are characteristic of the sand-binding species. There is a surprising amount of water at the depth of a few inches in the sand (cf. shingle-beaches, and the xerophily of the habitat is due chiefly to the great inducements to transpiration in the strong winds and the great reflected heat.

Experiments in fixing the shifting sands of the coast have been made. On the Holkham estate in Norfolk, pine-woods were planted. These have not only saved the adjoining fields and beautified the district, but have become commercially profitable.

Marram grass is being recommended for trial as a substitute for esparto grass in paper-making.

By comparison with English dunes, what has happened in New Zealand is very instructive. The dune area of North Island amounts to about 290,000 acres. Before man took possession, the dunes were protected by indigenous vegetation of *Spinifex hirsutus*; this covering was destroyed by fires, grazing and cultivation, and the dunes began to disperse over the more valuable land inland. Now man must re-fix them if that land is to be saved, and the succession of stages recommended by botanists is: (*a*) marram grass, (*b*) Californian tree-lupin, (*c*) native shrubs, (*d*) trees.

Shingle-Beaches. Chesil Bank in Dorset and Blakeney Point in Norfolk are the most notable of the many parts

of the coast where the sea has thrown up banks of material coarser than that of the sand-dunes. Miles of beach are built up principally of pebbles; these banks pass through regular phases of consolidation, and have a characteristic vegetation—the *Plant Formation of Shingle-Beaches*. Their thorough investigation is in progress at Blakeney Point under the direction of Professor F. W. Oliver, and there have been published at intervals reports which the student should read.

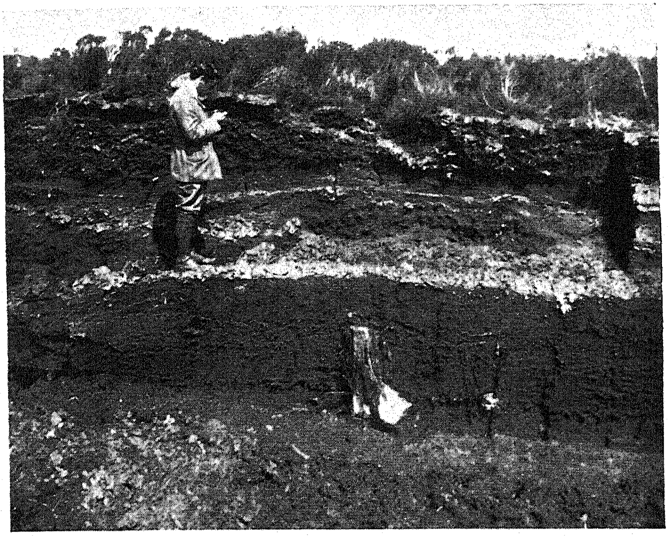
Shingle is not a hospitable habitat, least of all where it is mobile, i.e. kept on the move or in expectation of a periodical move by the waves. On the other hand, a better-class shingle-beach is not as bad as it looks. Its surface is very loosely thrown together, and rain-water passes through it very quickly, but even on hot days it will be found that there is moisture on the stones a foot or so down. We are told that when the adjoining pastures are failing owing to drought, sheep make their way down to Chesil Bank, and feed on the sea-campion (*Silene maritima*) and the sea-pea (*Lathyrus maritimus*), which show no signs of wilting. Sand fills in the interstices in lower layers, but a good deal of humus collects in the upper; it is derived from the decayed sea-drift of algæ, etc., thrown up by the tides, and is mixed with decayed stone, broken down by the lichens which encrust the pebbles. The source of the water-film on the pebbles is still rather a mystery, but it is supposed to originate in the dew which condenses on the free surface as well as in the spaces amongst the stones. This water is not salt. The ground water table is also nearly fresh and rests on a salt water table. At Dungeness, water is obtained from wells sunk in shingle.

Just as marram grass was a successful pioneer on sand-dunes, so on the shingle of Blakeney Point, the shrubby sea-blite (*Suæda fruticosa*) takes possession as an advance guard. Its seedlings, like those of all shingle plants, get a firm hold at once by their long roots. They can endure repeated immersion in sea-water. If the shingle rolls over a *Suæda* and flattens it out, it seems to respond as to a challenge; numerous new buds are stimulated into growth; from the new branches adventitious roots sprout and strike: repeat the burial and the resurrection repeats itself. The deeply buried limbs decay and become food for the new. The mat of buried branches acts as a net, holding gravel in place, whilst the bush itself, which may be several feet high, arrests some of the rolling stones and sand and may raise the crest of the dune. Professor Oliver recommends *S. fruticosa* as the best plant stabiliser for planting on shingle-banks. The sea-campion (*Silene maritima*) and the sea-purslane (*Arenaria peploides*) act in the same way. The saltwort (*Salsola Kali*) may be present on the lowest shingle beds. On the highest are found wanderers from sand-dunes and a few from farther inland.

Some of the shingle plants are halophytes, some are not.

The Salt-Marsh. In tidal estuaries and sheltered sea-bays there collects a certain type of soil subjected to certain definite conditions, which must be regarded as a stable habitat; its vegetation is recognised as the *Salt-marsh Formation*. The soils of the salt-marsh are either fine silts or sand, silt and clay in varying proportions. Their individuality depends on:

(*a*) The high or very high (but occasionally surprisingly low) percentage of common salt in the soil solution.



By courtesy of Dr. W. Munn Rankin and the "Naturalist"

FIG. 13. SECTION OF LOWLAND PEAT-MOOR. FOULSHAW IN LONSDALE

1. Present *Eriophorum-Calluna* moor, over which Birch seedlings are spreading.
2. Grey peat of *Sphagnum* moor.
3. Black peat of *Eriophorum* moor.
4. Layers containing timber of Birch and Scots Pine.

(*b*) Their liability to periodical flooding with sea-water. The land of the salt-marsh is built up from the repeated deposits of the tides, and consolidation is hastened as soon as plants get a footing. One fittest set of adventurers, the most tolerant of sea-water, prepares the way for others, raising the level of the mud-flat and assisting in drying its surface. In succession according to their degree of endurance of submergence and of salt, several zones make their appearance.

A purely aquatic zone is that of the grass-wracks (*Zostera*) which are mainly submerged; of them Warming says: "In consequence of the far-stretching rhizomes, a social mode of growth results, so that dense grass-green, submarine meadows, often extending for miles, are formed." In this close mat, the mud brought by the tides is held fast, and a bank arises exposed at low tide in the shallower water, on which the glassworts can live.

Three sets of salt-marshes in Britain have been carefully surveyed—Blakeney Point, the Hampshire coast, and the Dovey Estuary. The general features are the same; the component associations differ somewhat. The advance guard standing out to sea, representing the land plants, is either a zone of the glasswort (*Salicornia*) or the cord-grass (*Spartina*). The latter covers thousands of acres, and is spreading with great rapidity in Southampton Water and neighbouring inlets. *Spartina Townsendii*, limited to the Hampshire coasts, is remarkably easily propagated by fragments, can survive under three feet of flood-tide, and by its strong tangled, mat-like habit, behaves as a filter and as a breakwater. It is being recommended as a mud binder for reclaiming sea-flats.

A mixed crowd of halophytes takes possession next. It

may include *Glyceria maritima*, *Aster Tripolium*, *Atriplex* (*Obione*) *portulacoides*, *Suæda maritima*, etc.; the community may develop into a closed association dominated by sea-meadow-grass (*Glyceria maritima*) whose close, low sward is meadow-like.

A narrow belt of shallow mud may be covered almost entirely by sea-lavender (*Statice Limonium=Limonium vulgare*).

The next zone, on firmer soil, has often as dominant the sea-thrift (*Armeria maritima*), and the next again the red fescue-grass (*Festuca rubra*), at the same level with which may occur in hollows, associations of the sea-rush (*Juncus maritimus*). On the fairly consolidated ground, many other plants may be present in some profusion, e.g. sea-plantain, sea-spurry, scurvy-grass, sea-milkwort (*Glaux maritima*). Sea-weeds are strewn amongst the land plants of the lower levels, and their decay adds humus to the soil.

The plants of the salt-marsh are classed as halophytes, or partial halophytes, and are xerophytic. A common character amongst them is succulence, both in stems and leaves; this implies the storage of water in the tissue cells. Others have waxy or hairy protections against loss of water. Root systems are profusely branched and firmly anchored, and on the most exposed places the sub-aerial crowns are compact and squat. They are grazed down nearly to the soil. The flats are most valued pasture, the *Armeria* turf being reckoned the favourite with sheep and the most nutritious. Hence reclamation and preservation of sea-marshes is an economic problem.

CHAPTER XIV

CHAPTER XIV

HISTORICAL NOTES ON BRITISH VEGETATION

THIS chapter and the next will contain a few brief references to past events in the history of the plant-covering of our country, and to its possible modifications in the future.

A. *Vegetation of the Past in the British Isles*

Vegetation of Glacial Period. There are even some data which may be depended on to give a little insight into this far-away time. The picture of the British Isles which we must make for ourselves, according to the most generally accepted theory, is of a country resembling Greenland. An ice-sheet, very thick in the valleys, covered it from coast to coast; the southern edge of this sheet extended somewhere along the line of what is now the Thames Valley. The country was pretty certainly connected with the Continent in the south-east as least; and it is conjectured that the south-west of Ireland ran out much farther into the Atlantic. On this land-area which represented Britain, there would be living-room for plants only on the part south of the Thames line, on the theoretical extension to the south-west, and on the ice-free peaks and plateaus which, like the *nunataks* of Greenland, might rise like islands above the permanent ice-sheet. Lying thus adjacent to the snows, these tracts might yet support quite a fair variety of plant life. In the Swiss Alps, many beautiful flowers, e.g. *Soldanella, Ranunculus glacialis*, cushion silenes, alpine forget-me-

not, and glacial androsace are found at over ten thousand feet, in soil which is never free from the chill of ice water. Some species thrive only in low temperatures and brighten the very edge of the snow-fields. Still more striking is the occurrence of virgin forest at the foot of the glaciers in the Rockies of northern British Columbia.

A second theory about the glacial period in Britain denies the continuity of the ice-covering, and limits it to the higher valleys, attributing the evidence of ice action on the lower ground to floating ice over submerged land. This theory would provide for the existence of more land open to plants.

If an extensive area, free from ice, did lie south-west of Ireland, it might be presumed that its climate was markedly warmer than that of the present islands. It would, of course, support vegetation of less alpine type.

Post-glacial Vegetation. The climate became more genial, no doubt gradually; the ice-mass diminished, its edge retreating up the hills. It must have left behind it a surface of great irregularity. The rock débris which it had broken up, collected, and transported was of every description—from finest mud to boulders weighing tons. This "drift" it dropped in diverse forms—flat sheets, banks reared up against valley walls, huge morainic mounds, long ridges, multitudes of hummocks, etc.; countless in some localities would be the pools, meres, or even large lakes, held up on the clayey bottoms amongst these eminences. All this variety of natural feature would affect the populating of the ground with plants and animals. We need not imagine that a scene of barren desolation lay around for years after the retreat of the ice. More probably the army of colonists marched in

close at the heels of the departing ice. The process may be followed on a Swiss landscape; moraines within a stone's throw of the permanent ice-snout may be shining with many flowers, whilst woods of larch and pine grow within a quarter of a mile of it.

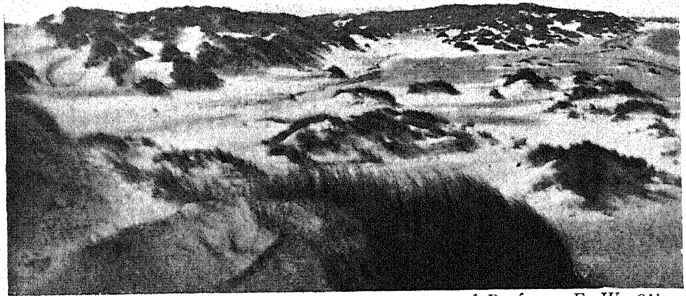
The first vegetation to establish itself in the British ice-cleared area would be that characteristic of cold climates. We know, in fact, that it included many plants now classed as alpine and many as arctic types. Marshland became crowded with rank growth, and later, great depth of peat accumulated. Forests grew; first they were of such as the dwarf arctic birch and willow; afterwards, there arrived Scots pine, oak, hazel, birch. Our knowledge of this part of botanical history is gained from the ancient peat beds. They indicate that oscillations of climate must have been experienced, for more than one forest-bed appears in the peat, the intervening layers representing periods when there flourished *Sphagnum*, cotton-grass or heaths. *The Lower Forest* of the peat (as seen in Scotland) was of birch, hazel, alder, and grew on heights up to two thousand feet; it grew also on the now treeless Hebrides and Shetlands. Then it was swamped in morass. *The Upper Forest* showed that the climate had again become drier. This forest extended from south to north of Scotland, but not into the islands. It capped heights of three thousand feet. We may think of it as covering at least ten times as much ground in Scotland as modern forest does. It was a forest of Scots pine. In it dwelt men of the New Stone Age.

Holderness, the most easterly division of the East Riding of Yorkshire, is a piece of country which is very helpful in reconstructing the post-glacial scene. Over it is

spread a thick crust of boulder clay. Within historic times there were dotted over it many small, shallow meres. All but one of these have been drained and farmed, or eaten into by the sea. Hornsea Mere is the last. The beds of these meres, as they were cut into on the coast, have given excellent cliff sections from which identifiable remains of plants—particularly fruits and seeds—have been collected.

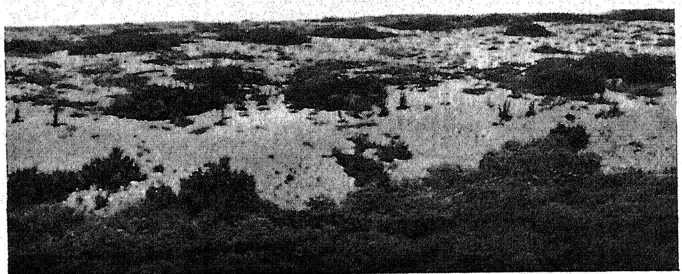
Where did the hosts of colonists come from? The three areas mentioned above would naturally be the first recruiting grounds. Then, as there is no reasonable doubt about the continuity of land from the Continent right across to Ireland, there would follow, as the climate grew more and more temperate, lowland types from central Europe. This region is, indeed, the main source of the existing British flora. Ireland parted company with Britain before migration was complete, hence the absence from Ireland of many British species.

If gradual amelioration of conditions made existence possible for lowland forms, it made it, on the other hand, at least very difficult for the arctic-alpine species; and competition in the long run ousted most of them from all but the higher hills. The relics of such a flora still exist. Their sanctuaries are the high mountains of Wales, northern England and the Grampians, together with a sea-coast habitat in West Ireland, which is more difficult to account for. One of the most remarkable plants is *Dryas octopetala*, an alpine, found in such diverse situations as the Swiss Alps, the Yorkshire hills, the Scottish Highlands, and, in magnificent luxuriance, at sea-level in Galway. Similarly, *Gentiana verna* occurs in Switzerland, on the Teesdale limestone, and on the sand-dunes of County Clare.



By courtesy of Professor F. W. Oliver

FIG. 14. SAND-DUNES AT BLAKENEY POINT, NORFOLK
The principal plant is *Psamma arenaria.*



By courtesy of Professor F. W. Oliver

FIG. 15. MAIN SHINGLE BEACH AT BLAKENEY POINT, NORFOLK
Three *Suaeda fruiticosa* zones are shown.

A third line of ancestry has left descendants. In the west of Ireland and in Devon and Cornwall a small but most interesting group of plants is mingled with the general flora. Their relationships are purely Mediterranean, particularly with Iberia and the south of France. One supposition about their origin is that they are migrants of post-glacial arrival, having travelled from the south of the Continent when a land connection still held. A second is that they re-entered from the south-western extension which lay beyond the extreme cold. A third is that they have been chance introductions, brought by wind, birds and other animals across seas. The most noteworthy of the plants are the three Irish heaths (Mediterranean, Mackay's and St. Dabeoc's), two Cornish heaths, the arbutus tree, the Irish butterwort, *Saxifraga Geum* and *S. umbrosa*.

There may have been a contribution from even a fourth direction—a very surprising one. In western Ireland and in the Hebrides there exist a few species whose nearest other stations are in North America. The list includes only these—the blue-eyed grass (*Iridaceæ*), pipewort, two other water-plants and an orchid. Their presence is very puzzling. One theory explains them by means of a long-lost continent, which bridged the Atlantic between Ireland and America.

Summing up, we have four groups of plant settlers:

(*a*) The main body of the flora from central Europe.

(*b*) The arctic-alpine flora of the mountains.

(*c*) The Mediterranean species in south-west Ireland and south-west England.

(*d*) The American element in West Ireland and the Hebrides.

Vegetation in Early Historic Times. We know a good deal about the appearance of the country in the earliest days of authenticated history. One fact stands out with amazing clearness—namely, that the conditions in the British Isles are essentially favourable to *woodland*. We have to remember, in this connection, that no material change in climate has occurred between that time and the present.

Grass, no doubt, was the natural and only possible growth on some of the mountains and on the thin soils lying on the Mountain limestones and the chalk. The steepest slopes would be bare. But by far the greatest proportion of land on which vegetation could have grown bore forest or was marsh or lake. For a long time the cultivated areas were negligible in extent.

The Andredsweald was a forest one hundred and twenty miles long from east to west, covering the Weald and much of Hants; as a barrier it helped to isolate the invading tribes of Jutes and South Saxons. Selwood lay east of Somerset. Other thick woods began near Hampstead and ended near the Wash. Immense forests covered the clay lands in central England; the basin of the Trent was filled with them; Charnwood, Sherwood and Needwood are relics of them. The south of Scotland is spoken of in ancient documents as being one great forest; by this we must understand a "hunting-forest," i.e. land sparsely inhabited, often bare and desolate, studded with woods, but not continuously clothed with them. Ettrick Forest is one famous section of it, in which there still exist a few patches of natural woodland of birch and oak, e.g. near Ashestiel. Of the great pine-woods of the Mid-Grampians there are left only veteran trees,

solitary or in groups, in the Black Wood of Rannoch, at the foot of Lochnagar, on Loch Arkaig, in Glen Nevis, and in the Forest of Rothiemurchus. Farther north, there are old woods near Loch Maree and Ullapool.

Going back to prehistoric times, we learn that the comparatively dry climate of the time of the Upper Forest Bed in the peat must have changed to one much wetter. Swamp extended, and wet mosses choked the roots of the forest trees. Peat increased in thickness. The forests of the Irish Plain, for instance, were overwhelmed—hence the bog-oak embedded in them. In continuation of this, great areas in early historic times were morasses, which had an equal share with forests in determining the lines of advance of invading tribes, and the boundaries of their settlements. Amongst the most extensive of these swamps were: Romney Marsh, to the east of the South Saxons; the basin of the Lea, between Herts and Essex; the great arc sweeping round the Wash, cutting off East Anglia from the Midlands; the flats which carried the estuarial tract of the Humber up the basins of the Trent and the Yorkshire Ouse; the morasses of Somerset; Solway Moss; the wide Carse at the head of the Firth of Forth.

In the north of England particularly, a great deal of land was under lakes, large and small. The place names show how numerous they must have been in districts where now is cultivated land.

CHAPTER XV

CHAPTER XV

HISTORICAL NOTES ON BRITISH VEGETATION (*continued*)

B. *Transition to Existing Surface Conditions*

THE disappearance of woodland in historic times has not been due to extension of marsh, for, except in a few localities, peat has been breaking up naturally rather than growing thicker. Man has been the responsible agent, acting in many ways.

(*a*) Forests were rare cover for an enemy. We hear that, as far as could be done, Roman roads were kept outside them, but if they were made through them, a distance of seventy yards on either side was cleared of trees. Also, that a great pine-wood in south-east Yorkshire was burnt down in order to "smoke out" the British refugees. No doubt the Saxons helped on destruction in the same fashion to secure safety for themselves. One historian says that when John of Gaunt invaded Scotland in 1380, eighty thousand axes could be heard at one and the same time felling the timber.

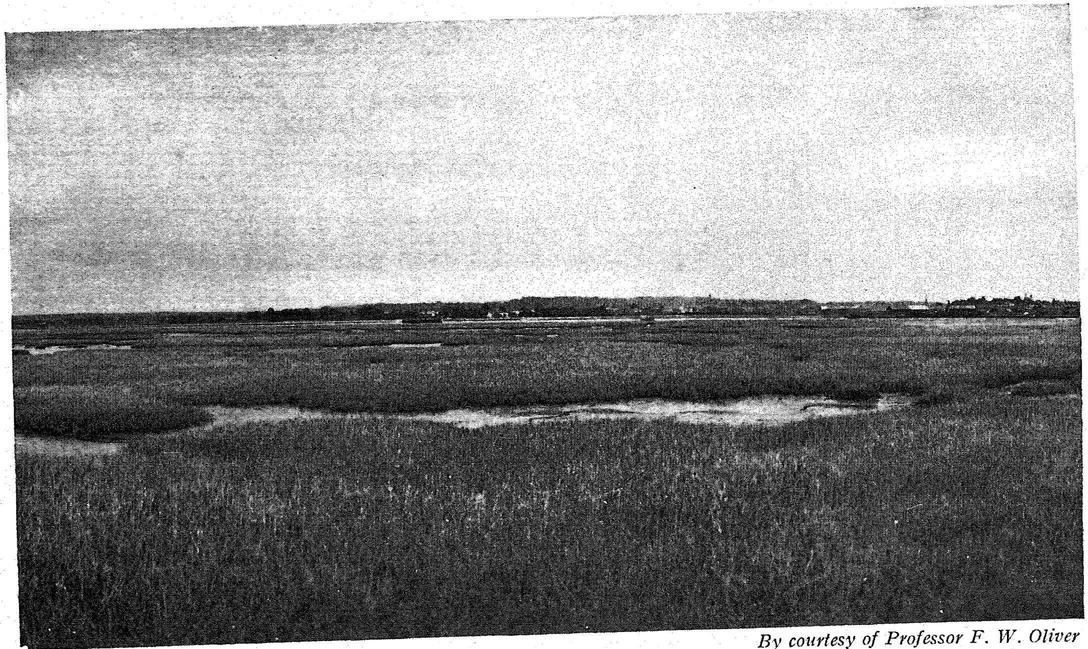
(*b*) For many hundreds of years, man went to the woods for his fuel, and for his house-building and boat-building material. As he grew in numbers, so would his needs grow; forests would have to be sacrificed to build his villages and his towns. The general use of coal seems to have spread first in Scotland, in the sixteenth century. A sixteenth-century writer, Hector Boece, gives a curious

insight into the way in which it was regarded: "In Fyffe ar won blak stanis, quhilk hes sa intollerable heit, quhen thay ar kindillit, that thay resolve and meltis irne, and ar thairfore richt proffitable for operation of smithis."

(*c*) Incalculable is the woodland which has fallen for the needs of iron-smelting. The havoc began when the men of the Iron Age wanted iron for their axes; so, on from those days more than a thousand years before Christ up to the beginning of the nineteenth century, the toll was being taken. So grave became the outlook that laws to limit the inroads had to be made. In 1556, iron-smelting was forbidden in Sussex. Increased activity elsewhere followed, e.g. in the Midlands and in Lancashire. Scotland at the beginning of the seventeenth century was legislating to stay the ruin, but without great effect. In the eighteenth century, ore was even carried from England to the Highland forests. In Scotland alone, nearly a hundred old slag-furnaces (bloomeries) have been identified. A few were in the south of Scotland; many in Argyle, between Loch Long and Loch Fyne, in Perthshire, in Strathspey and the parallel valleys, some near Loch Etive, and others even round the distant Loch Maree.

(*d*) Forests, as harbouring wild beasts, were sacrificed when the dangers became pressing. This was very true of Scotland, and usually for the purpose of extirpating wolves. Records proving this are found for Rannoch, Blair Athol, Lochaber, etc.

(*e*) Most of the land cleared for the reasons stated above was invaded by heath or rough grass moor. In contrast with this, we find that man cut down more and more



By courtesy of Professor F. W. Oliver

FIG. 16. *Spartina Townsendii* IN POOLE HARBOUR

The nearly continuous sheet of *Spartina* developed from a few scattered clumps, between 1911–24.

wood to secure good land for pasture and for tillage. In the neighbourhood of his settlements, too, woods were spoilt by his domestic animals, young saplings always falling a prey to goats, sheep and cattle.

The reclaiming of marshland has not been easy, owing to the low level at which much of it lies. The fall to the sea being so slight, the liability to river-floods, and on the coast to sea-floods, necessitates constant care. It was in the first years of the seventeenth century that private owners began the draining of the eastern swamps of England. It was not till nearly a hundred years later that the work was done effectually with the help of Dutch engineers.

Lakes have been got rid of by draining. Nature has assisted through the silting up of the beds by wind-borne and water-borne débris.

A brief note or two on agricultural changes must suffice. There is a striking enough contrast between the England of to-day parcelled out almost completely into compact farms and the unfenced England of Saxon times, in which the arable lands were the common property of the village and the adjacent wastes were open pasture. The Saxon grew oats, wheat and rye for his bread, and barley for his beer—nothing else. He knew that land could be exhausted by crops, so he grew wheat on it one year, barley the next, and left it fallow, or idle, for the third.

For centuries no material changes were made, except that private ownership gradually took the place of communal, and some enclosures were made. More land was tilled.

In the fifteenth and sixteenth centuries, the tremendous

demand for wool, and other causes, threw back a great deal of arable land into pasture.

It was in the eighteenth century that the agricultural industry was revolutionised. The open field system was given up and farms were planned out; between 1760 and 1770 a thousand enclosure bills were passed. New crops were introduced. Far more potatoes were cultivated, and the important crops of clover and lucerne were tried. Still more far-reaching in its effect was the adoption of the turnip crop as one in the rotation. It was substituted for the "fallow" year of the preceding centuries; this, of course, meant the addition of one-third more of cultivable land in England. Manures came into general use, and implements were improved.

C. *Vegetation of the Future in the British Isles*

Within the area of these Islands there exist quite peculiar difficulties to be tackled. Small islands with a steadily growing population, a highly concentrated industrialism of mining and manufacturing which has taken possession of much land, agriculture not a source of national wealth, dependence on other countries for the nation's food—all the facts point to its being a state duty to encourage scientific research and its application to agriculture, to demand that there should be no waste land in the country, and no land which is not producing its utmost.

Progress is being made. The farmer whose motto was that what was good enough for his father was good enough for him is disappearing. In some localities, for many years, the farmer has been fully alive to the need for utilising

every discovery of science. Universities have more extensively directed their research to practical applications of their theories. A certain amount of Government aid has been forthcoming for furthering scientific agricultural inquiry.

To get from arable land its highest yield involves knowledge of the methods of obtaining the finest tilth (texture of soil), of feeding the ground with manures, of selecting the most profitable form of crop and the variety of it best adapted to each soil and climate, of economic and sound methods of harvesting, etc., of perfection of implement employed. In all, a wide field for error or the detection of error.

As the botanical foundation for specialised agricultural research must stand general experimental and observational study of plant structure and physiology. Such a course aims at a knowledge of the internal working of the plant's organisation, the reasons for the specific responses which it makes to specific external factors. This belongs to a general University Course.

The soil and its relations with the plant have formed the special subject of investigation at the Rothamstead Experimental Station (Herts) for nearly eighty years. Discoveries made there in respect of fertilisers and how to apply them have been almost revolutionary in effect. Amongst the many questions which are being dealt with there are: the behaviour of the living things in the soil which affect plants (e.g. protozoa and bacteria); the chemistry of the soil; the safest, most effective, cheapest fertilisers; how to obtain sufficient organic manure or substitutes for it; the destruction of weeds; the physical character of the soil; how to improve tilth.

Another line of research is being followed in the Plant Breeding Institute at Cambridge. By selection, by crossing, etc., great modifications can be induced and perpetuated in plants. In wheat, for example, hundreds of varieties have been evolved. Many aims are kept in view: increase in yield, shortening of ripening season, good milling or baking qualities, immunity from disease, etc. Wheat, oats, barley, potatoes, are all receiving attention. At Aberystwith, the investigators concentrate on herbage plants.

At various stations throughout the country work is directed towards discovering the inducing causes of plant diseases and the best means of prevention and cure. Amongst such pests are wart disease in potatoes, turnip diseases, rusts in cereals, etc.

At East Malling, in Kent, fruit crops are the subject of special investigations; in the north of Ireland experiments in flax-growing are being conducted; Cambridge carries on research in animal breeding and feeding-stuffs; Oxford specialises in agricultural engineering. This is an illustrative, not an exhaustive list of research stations. There are, in addition to these, many Advisory Centres to which the practical cultivator may make application for counsel.

The North of Scotland Agricultural College at Aberdeen concentrates on the mineral characteristics of soils. The workers there have made a discovery of great agricultural importance in tracing the cause of the radical difference which exists between the soils of the Highlands of Scotland, the north of Ireland and of Wales on the one hand, and those of England (particularly in the south-east) on the other hand. The former are derived chiefly from the

ancient igneous and metamorphic rocks, and their mineral constituents have undergone comparatively little alteration; they contain abundance of valuable plant food. In the second region the rocks are mainly sedimentary, of Secondary and Tertiary age. The materials of which they are composed have been subjected to prolonged and repeated weathering; the original minerals such as silicates have been decomposed. The soils of the three regions of older rocks, in general, are acid in their reaction. They have nevertheless, in cultivation, shown themselves surprisingly fertile; the addition of lime does not increase their productivity in any appreciable degree. The new theory explains this. They are independent of calcium carbonate as such, because they contain reserves of lime and potash locked up in the form of unaltered silicates. From these, the lime and other bases can be set free gradually and utilised by vegetation.

Afforestation is now of even more moment than before the Great War. If the laws of the country intervened two or three centuries ago to call a halt in the demolition of forests, there would seem to be equal need at the present day for them to concern themselves with enforcing the proper management of such as survive and of replacing some of those which have vanished. The strictly scientific, state-controlled forestry of the Continent has no parallel in Britain.

A pre-war Report on Afforestation issued by a Royal Commission expressed the conviction that immediate action should be taken to re-plant forests and to alter methods of forest management. It gave nine million acres as being the amount of land now unused but available

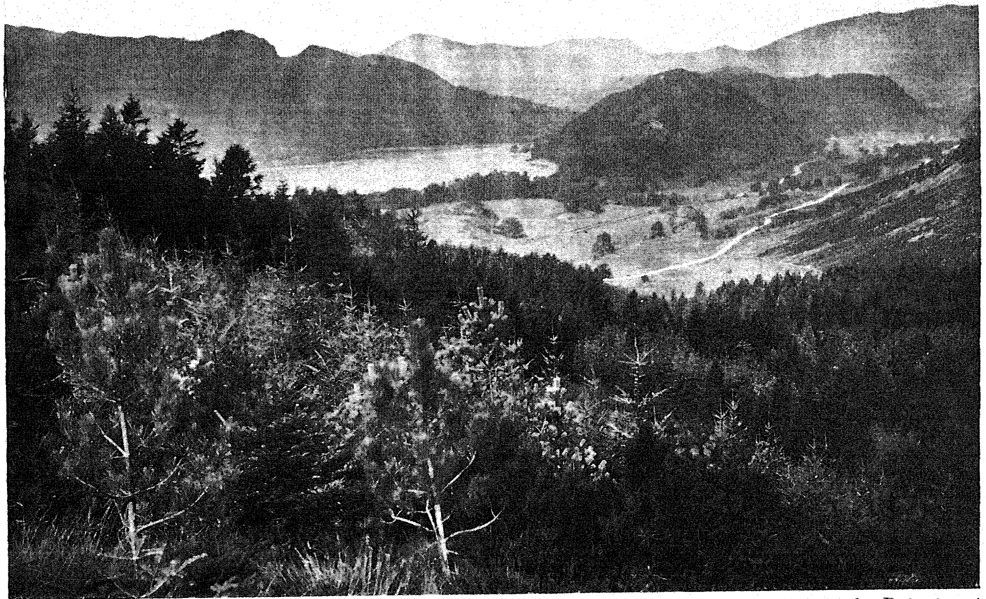
for woodland. It outlined a Government scheme of afforestation. The Government has bought for testing purposes an estate of twelve thousand acres near Loch Awe.

Much experimental work is necessary before laying down rules for British Sylviculture; no Continental experience can safely be applied without testing it on our soils and in our climate. One rule which seems unquestionably worth adopting is that of planting trees very thickly, to prevent frequent branching and to get timber free from knots.

Hill-slopes and moorland with peat are areas which might often profitably be planted with trees. The moor, which, of course, is of very varying type, presents considerable difficulty, and Continental forestry tries many experiments with it. If *Pan* is present in such a moor it must be broken up with heavy ploughs and brought to the surface. It is said that Scots pine will grow wherever heath will grow.

The planting of the catchment areas from which the water-reservoirs of large cities are fed is a question on which there has been long-standing, and great difference of opinion. More than twenty years ago, Leeds planted many acres of wood on its collecting grounds near Blubberhouses, at a time when the idea was strongly advocated. The latest report of a Corporation Committee (Bradford, 1923) is highly condemnatory, declaring woodland to be a source of contamination for the water and maintaining that the ideal watershed is clean and bare, one from which water is quickly collected.

Trees are valuable for planting on sand-dunes after



Photo, G. P. Abraham. By courtesy of Manchester Waterworks Department

FIG. 17. AFFORESTATION: MANCHESTER WATERWORKS ESTATE AT THIRLEMERE

Plantation of Spruce and Douglas Fir, planted 1911–12. Interspersed are spruce-trees thirty-eight years old.

these have been partly fixed by other plants. They prevent sand from blowing inland. For example, *Pinus maritima* has been used on the Norfolk coast.

Coastal loss and gain of land. This concerns agriculture very closely.

The losses are great, but unevenly distributed. One of the regions which has suffered most severely is the coast of Holderness. The boulder clay cliffs there are being cut back at an average rate of about seven feet per annum. One estimate puts the loss, basing it on the rate not having altered, as having been about eighty-three square miles since the Roman occupation. Many villages have disappeared entirely, e.g. Ravenser (Ravenspur), which lay to the east of Spurn Headland. Others have moved their sites inland by degrees. North Norfolk is also losing ground; so are parts of Lancashire. A Royal Commission appointed to consider Coast Erosion reported that between 1848–93, 774 acres were lost from Yorkshire, but 2178 acres were reclaimed within the Humber area. Many modes of protecting the shore, groynes for example, have been tried, but none is infallible.

Compensating land-gain is considerable in many places. The very agents which are carrying away Holderness are heaping up mud, gravel and sand on the coasts farther south. Spurn Head is growing; new land is being made by currents within the Humber; miles of sediment are accumulating in the Wash. The Norfolk Broads are receiving wind-blown and sea-carried sand, which is banking up and silting up marsh and lagoon. Kent is growing seawards in Romney Marsh and Dungeness; dunes are adding to the coasts in Devon and Cornwall and elsewhere.

All such new land must be "fixed" as soon as possible by planting suitable vegetation. Marram grass is one of the best binders for sand-dunes and *Suæda fruticosa* for shingle-beaches. At a later stage, pinewoods are successful on English sand-dunes.

BOOKS OF REFERENCE

BOOKS OF REFERENCE

BULLER, A. H. R., *Essays on Wheat.* New York. 1919.

COLE, GRENVILLE A., *Ireland the Outpost.* Oxford, 1919.

CRAMPTON, C. B., and MACGREGOR, M., "The Plant Ecology of Ben Armine, Sutherlandshire," *Scottish Geographical Magazine*, xxix. 1913; "The Geological Relations of Stable and Migratory Plant Formations," *Scottish Botanical Review*, i. 1912.
Vide Smith, W. G.

ELGEE, F., *The Moorlands of North-east Yorkshire.* London. 1912.

FARROW, E. P., "On the Ecology of the Vegetation of Breckland," *Journal of Ecology.* Dec. 1915, June 1916, March 1917, June 1917, Dec. 1917, June 1918, May 1919.

FARROW, E. P., *Plant Life on East Anglian Heaths.* Cambridge Press. 1926.

GEIKIE, SIR A., *Landscape in History*, 1905; *The Scenery of Scotland.* 1907.

HAMPSTEAD SCIENTIFIC SOCIETY, *Hampstead Heath : its Geology and Natural History.* London. 1913.

HILL, T. G., and HANLEY, J. A., "The Structure and Content of Shingle Beaches," *Journal of Ecology.* March 1914.

MARSH, A. S., "The Maritime Ecology of Holme-next-the-Sea," *Journal of Ecology.* June 1915.

MOSS, C. E., *Vegetation of the Peak District.* 1913.

MOSS, C. E., RANKIN, W. M., and TANSLEY, A. G., "The Woodlands of England," *New Phytologist*, vol. ix. March and April 1910.
Vide Smith, W. G.

OLIVER, F. W., "Some remarks on Blakeney Point, Norfolk," *Journal of Ecology.* March 1913.

OLIVER, F. W., and SALISBURY, E. J., "Vegetation and Mobile ground, as Illustrated by *Suæda fruticosa* on Shingle," *Journal of Ecology.* December 1913; "The Shingle Beach as a Plant Habitat," *New Phytologist*, vol. ii., 1912.

PETHYBRIDGE, G. H., and PRAEGER, R. Ll., "The Vegetation of the District lying South of Dublin," *Proceedings of Royal Irish Academy*, vol. xxv., sect. B 6, 1905.

PRAEGER, R. Ll., *A Tourist's Flora of the West of Ireland.* Dublin. 1909.

RASTALL, R. H., *Agricultural Geology.* 1916.

RANKIN, W. M., *vide* Moss, C. L., and Smith, W. G.

REID, CLEMENT, "The Relation of the present Plant Population of the British Isles to the Glacial Period," *Journal of Ecology*. March 1913.

SALISBURY, E. J., "The Significance of the Calcicolous Habit," *Journal of Ecology*. December 1920.
Vide Oliver, F. W.

SCHIMPER, A. F. W., *Plant Geography upon a Physiological Basis*. Oxford. 1903. Translation.

SCHARFF, R. F., "British Flora," *Irish Naturalist*. 1912.

SHEPPARD, T., *The Lost Towns of the Yorkshire Coast*. 1912.

SMITH, R., "Botanical Survey of Scotland." Parts I. and II. *Scottish Geographical Magazine*. 1900.

SMITH, W. G., "The Distribution of *Nardus stricta* in Relation to Peat," *Journal of Ecology*. March 1918; "Raunkiaer's 'Life-Forms' and Statistical Methods," *Journal of Ecology*. March 1913.

SMITH, W. G., and CRAMPTON, C. B., "Grassland in Britain," *Journal of Agricultural Science*, vi. 1914.

SMITH, W. G., and MOSS, C. E., "Geographical Distribution of Vegetation in Yorkshire. Part I., Leeds and Halifax District," *Geographical Journal*. April 1903.

SMITH, W. G., and RANKIN, W. M., "Geographical Distribution of Vegetation in Yorkshire. Part II., Harrogate and Skipton District," *Geographical Journal*. 1903.

STATHER, J. W. S., "Shelly Clay dredged from Dogger Bank," *Quarterly Journal of the Geological Society*, vol. lxvii. 1912.

STAPF, O., "The Southern Element in the British Flora," *Proceedings of the Linnean Society*, *129th Session*.

TANSLEY, A. G. (Editor), *Types of British Vegetation*, 1911; "The Classification of Vegetation and the Concept of Development," *Journal of Ecology*. June 1920; *Practical Plant Ecology*. 1923.
Vide Moss, C. E.

WILKINS, V. E., *Agricultural Research and the Farmer*. 1922; *Research and the Land*. 1926.

YAPP, R. H., JOHNS, D., and JONES, O. T., "Salt Marshes of the Dovey Estuary," *Journal of Ecology*. March 1916 and June 1917.

INDEX

D

E